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AD-A175 678

Report No. 6255

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# A COMPACT TREATMENT PACKAGE FOR ACOUSTIC SUPPRESSION OF THE STANDARD U.S. DOD 30 KW DIESEL ENGINE-DRIVEN GENERATOR SET


by

Paul J. Remington

and

Matthew Rubin


May 1986



Prepared for:

Belvoir Research Development and Engineering Center
Ft. Belvoir, VA 22060-5606

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10 Moulton Street
Cambridge, MA 02238

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| REPORT DOCUMENTATION PAGE | | READ INSTRUCTIONS BEFORE COMPLETING FORM |
|---|---|---|
| 1. REPORT NUMBER | 2. GOVT ACCESSION NO. ADA175678 | 3. RECIPIENT'S CATALOG NUMBER |
| 4. TITLE (and Subtitle) A COMPACT TREATMENT PACKAGE FOR ACOUSTIC SUPPRESSION OF THE STANDARD U.S. DOD 30 KW DIESEL ENGINE-DRIVEN GENERATOR SET | | 5. TYPE OF REPORT & PERIOD COVERED Final (Nov. 1983 - May 1986) |
| | | 6. PERFORMING ORG. REPORT NUMBER 6255 |
| 7. AUTHOR(s) Paul J. Remington; Matthew N. Rubin | | 8. CONTRACT OR GRANT NUMBER(s) DAAK70-84-C-0001 |
| 9. PERFORMING ORGANIZATION NAME AND ADDRESS BBN Laboratories Incorporated, 10 Moulton Street, Cambridge, MA 02238 | | 10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS |
| 11. CONTROLLING OFFICE NAME AND ADDRESS Combat Engineering Directorate, U.S. Army Belvoir Research Development & Engineering Center, Ft. Belvoir, VA 22060-5606 | | 12. REPORT DATE May 1986 |
| | | 13. NUMBER OF PAGES 144 |
| 14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office) NA | | 15. SECURITY CLASS. (of this report) UNCLASSIFIED |
| | | 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE |

16. DISTRIBUTION STATEMENT (of this Report)

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17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Diesel Generators,
Noise Control, and
Acoustic Signature Suppression. K

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report documents the results of a recent, successful project to develop a retrofit treatment package to reduce the acoustic signature of standard U.S. DOD 30 kW diesel engine-driven generator sets. The treatment resulting from this development reduces the detection distance of such generator sets by a factor of 3 in a compact package.

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# 1. INTRODUCTION

## 1.1 Background

The standard U. S. DOD diesel engine-driven generator sets, of which the 30KW set shown in Fig. 1 is one, provide an economical source of reliable, transportable electric power for military equipment and installations world wide. A major drawback of these units, however, is the noise that they generate. Not only is this noise a potential health and safety hazard and source of annoyance (exceeding recent NATO "good neighbor policy" limits), but it also can act as a beacon allowing unfriendly forces to detect, classify and locate any Army installation or weapon system powered by these units.

FIG. 1. PHOTOGRAPH OF THE UNTREATED U.S. DOD STANDARD 30 KW DIESEL ENGINE-DRIVEN GENERATOR SET.

Recognizing the potential of this acoustic threat, the Combat Engineering Directorate of the U. S. Army Belvoir Research Development and Engineering Center (BRDEC) began an investigation into the acoustic suppression of diesel engine-driven generator sets. The intent was to develop an interim measure that could be applied on a retrofit basis until new generator designs could be developed by the Army. The focus of the investigation was the 30 KW diesel generator. The reasons for selection of this particular generator were twofold. First, the 30 KW unit is used as the main source of power in many of the U. S. Army's mobile weapon systems. Many of these systems rely on being able to hide from enemy forces in order to increase their probability of survival until the time comes to launch their weapons. For these weapons systems the acoustic emissions from the diesel generator can threaten the survival and reduce the military worth of the entire system. Therefore acoustic suppression of the 30 KW unit is of central interest to the Army. In addition the 30 KW unit has two sister units of different electrical capacity: 15 KW and 60 KW. While the three units are not identical they are sufficiently similar that noise suppression technology developed for the 30 KW will be extremely helpful in developing suppression technology for the other two generators.

The investigation was carried out in two phases. The first phase, reported in detail in Ref. 1, involved the definition of the noise reduction goals of the program, a detailed diagnosis of the sources of noise in the set, the specification of treatments to reduce the emissions from those sources and the identification of the cost and weight penalties due to the installation of the identified treatments. The goal of the program was defined early in the first phase. It was decided that the noise emissions from the set should be reduced to a level that would ensure that the generator could not be heard with the unaided human ear at distances greater than 500 meters. That goal was, then, used to define the maximum noise level as a function of frequency at a

distance of 7.5 meters from the set such that achieving the inaudibility goal at 500 meters would be ensured. With the help of the diagnostic measurements that defined the noise emissions from each source, it was possible to estimate with reasonable certainty for various combinations of treatments the reduction in noise, the increase in size, weight and cost of a treated set. Figure 2 shows the result of one of those estimates. The figure shows the increase in weight as a function of the distance at which the set can be heard with the unaided human ear.

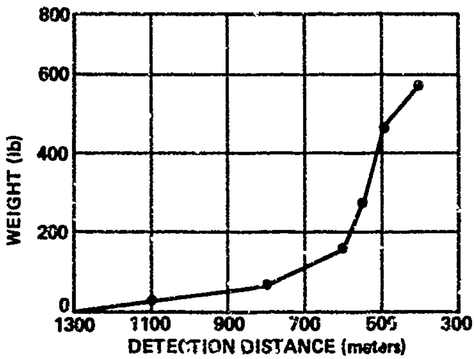



FIG. 2. ESTIMATED WEIGHT PENALTIES OF THE NOISE CONTROL TREATMENTS AS A FUNCTION OF THE DISTANCE AT WHICH THE 30 KW DIESEL GENERATOR CAN BE HEARED WITH THE UNAIDED HUMAN EAR.

A significant constraint on the design of the noise control treatments was the allowable increase in size or outer dimensions of the set needed to accommodate the treatments. In the primary application of concern for this program, the generator units will be mounted on the back of a MAN tractor just aft of the cab as shown in Fig. 3. To quantify this envelope BBN Laboratories personnel visited the Martin Marietta plant in Orlando, FL, and measured the space for expansion of the set's dimensions. The

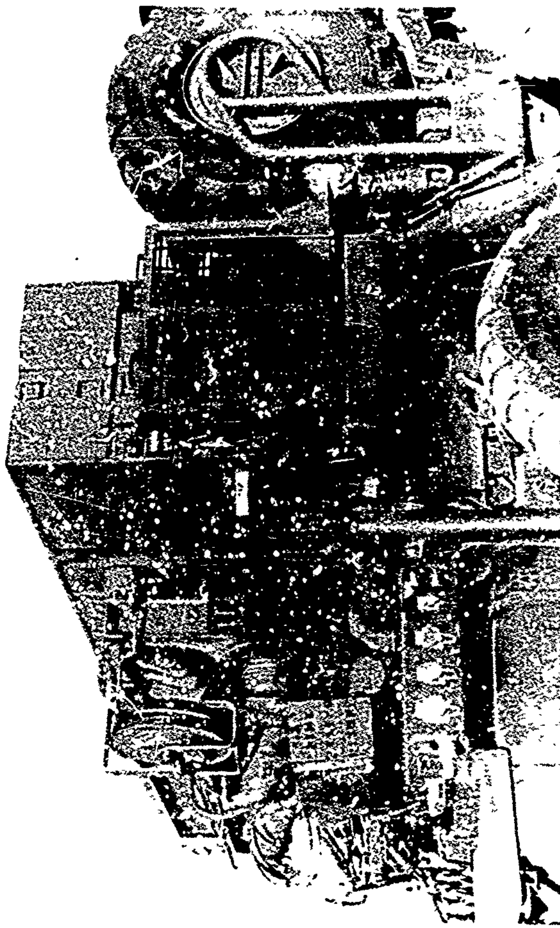


FIG. 3. THE 30 KW GENERATOR INSTALLED ON THE BACK OF THE M.A.N. TRACTOR.

resulting envelopes for three segments along the length of the generator are shown in Fig. 4. The generator sits crosswise on the tractor with its radiator end at the left side and the generator end (with the control panel) at the right side of the tractor. No projections from the radiator end of the generator are possible during transport because these would extend beyond the the side of the tractor and increase its width. Only minimal projections are possible at the generator end of the set because of an operator platform that folds up against the generator. Finally it was found that the height of the set could be readily increased by up to 12 in. before tractor height restrictions would be of any concern.

The second phase of this project which is the subject of this report, involved the construction and test of two prototype quieted 30 KW generators: a fully treated and a partially treated set. The suite of treatments chosen for the fully treated set included all of the treatments as defined in phase 1 that were required to reduce the detection distance to 500 meters or less. The treatments for the partially treated set were chosen to be those required as defined in phase 1 to achieve a reduction in detection distance to about 600 meters. That set of treatments is just sufficient to bring us to the point shown in Fig. 2 where weight penalties begin to rise very rapidly with decreases in detection distance. Consequently the partially treated set represents the quietest set achievable with minimum increase in weight.

## 1.2 Overview of the Treatments

For the fully treated generator, the suite of noise control treatments identified in phase 1 to reduce the detection distance to 500 meters or less consisted of,

- an enlarged reactive engine exhaust muffler,
- a silencer for the engine combustion air intake,

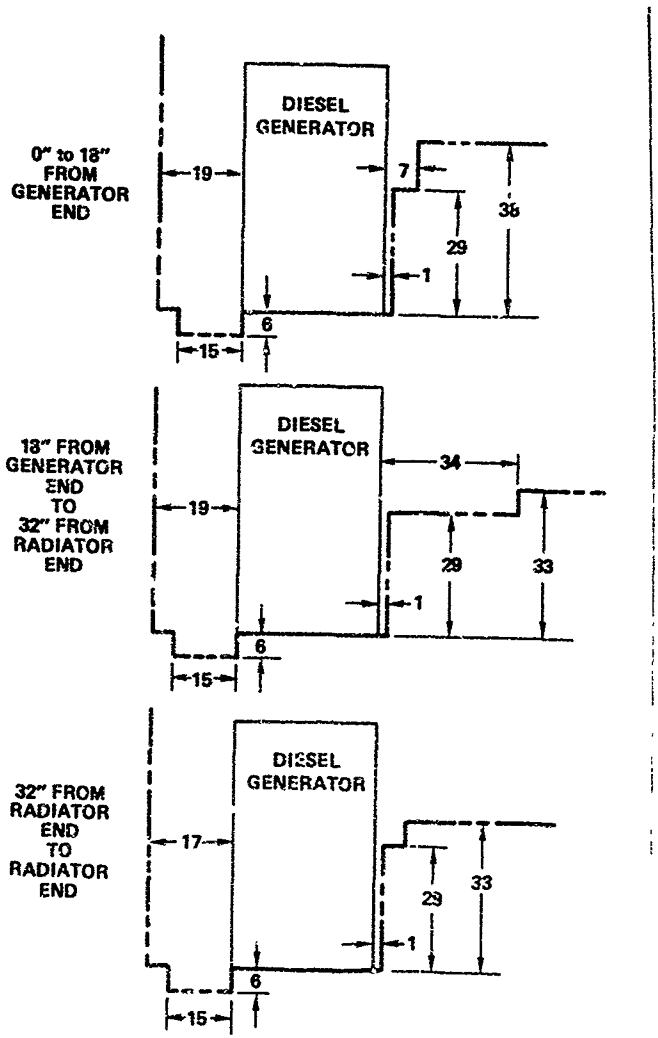



FIG. 4. THE INSTALLATION ENVELOPE AROUND THE 30 KW GENERATOR ON THE M.A.N. TRACTOR.

- a reduction in cooling fan speed while maintaining water pump speed,
- enlarged cooling air inlet openings in the housing to compensate for the reduced fan speed
- silencers for the cooling air intake and discharge openings in the set housing,
- rubber mounts to isolate the engine/generator vibration from the housing
- sound absorbing treatments for the interior of the housing
- improved door seals and
- vibration damping treatments for the oil pan and engine combustion air intake silencer

The suite of treatments identified in phase 1 for the partially treated generator was a subset of the above treatments and consisted of

- an enlarged reactive engine exhaust muffler,
- a silencer for the engine combustion air intake,
- a reduction in cooling fan speed while maintaining water pump speed,
- enlarged cooling air inlet openings in the housing to compensate for the reduced fan speed

During phase 2 the design of each of these treatments was refined in preparation for fabrication and installation on the prototype generators. Details of each of these treatments as well as a complete set of drawings can be found in subsequent sections of this report.

## 1.3 Approach

We began the second phase by constructing two pre-prototypes of the fully quieted generator. The purpose was to check the acoustic performance of the designs in a form that could be easily modified. For example, silencers for the cooling air inlet and discha: · ᐣ were constructed of bare glass fiber mat and plywood, housing modifications were constructed of plywood, improved door seals were simulated using duct tape, bare glass fiber mat was attached to the interior walls of the housing to simulate housing absorptive treatment, etc. Some treatments that could not be simulated in easily modifiable form, were installed in what we assumed would be their final form. These included engine exhaust and engine inlet silencers and the rubber vibration isolation mounts between the engine/generator and the housing. The pre-prototypes were then tested to ensure that they achieved the goals of the program. Tests included measurement of the acoustic signature, cooling air flow through the set and tests of cooling system performance in high ambient temperatures.

When the pre-prototype designs successfully passed these tests, final versions of all the treatments were fabricated and installed on the generator. The fully treated prototype generator was then tested to ensure that it satisfied the goals of the program. Subsequent to the completion of the fully treated unit the partially treated unit, configured as described above, was constructed and the reduction in noise measured.

## 1.4 Organization of the Report

Details of the individual acoustic treatments for both prototypes are discussed in the next section. Acoustic performance, cooling system performance and weight penalties are discussed in Sec. 3. Conclusions can be found in Sec 4, and the detailed drawings of the treatments and materials list can be found in the Appendix.

## 2. TREATMENT DESCRIPTION

The fully treated 30 KW diesel generator set is shown in Fig. 5. By comparing Figs. 1 and 5 one can see that, from the outside, the treated and untreated sets are not significantly different in appearance. The most noticeable difference is that the treated set is about 12 in. higher than the untreated set. Additionally the removable silencers at the intake and discharge openings to the housing are also evident when installed.

The real differences between the treated and untreated sets does not become noticeable until one looks inside the housing. Figure 6 shows a cut away drawing of the fully treated generator set with all treatments installed. There are seven primary treatments each focused on a particular noise source and a number of auxiliary treatments designed to enhance the acoustic performance of a primary treatment or minimize its impact on set performance.

Figure 7 shows the results of a source diagnosis carried out on the set [1]. The figure presents the noise generated by each important source (7.5 meters from the radiator end of the set) as a function of frequency. As the figure illustrates, the exhaust, intake and cooling fan were the loudest sources and clearly had to be treated if any progress was to be made in reducing the acoustic detectability of the set. In addition, both airborne and structureborne noise from the housing (primarily due to the diesel engine) had to be treated if the 400 meter detection criterion, also illustrated in the figure, was to be achieved. Although the specified goal of the program was to reduce distance at which the set can be heard to 500 meters or less, we used the 400 detection criterion as our design goal to allow for an adequate margin of safety. In the remainder of this section we will discuss the design and development of the treatments used to control the noise from each of these five sources.

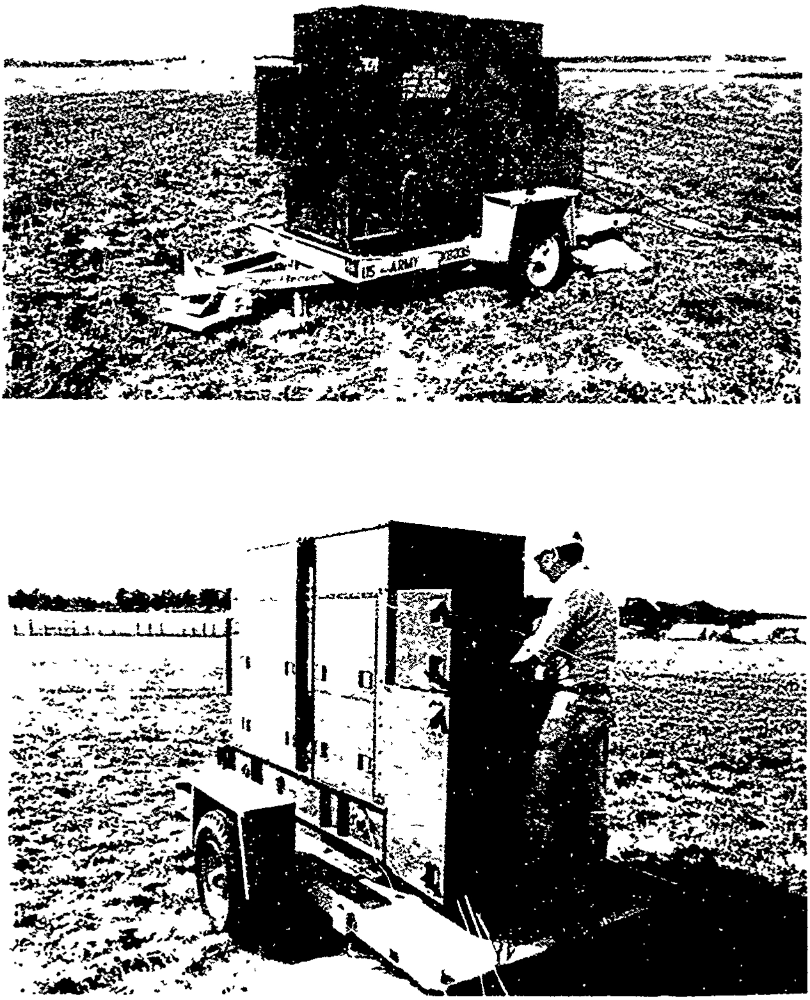



FIG. 5. PHOTOGRAPH OF THE FULLY TREATED 30 KW DIESEL GENERATOR SET.

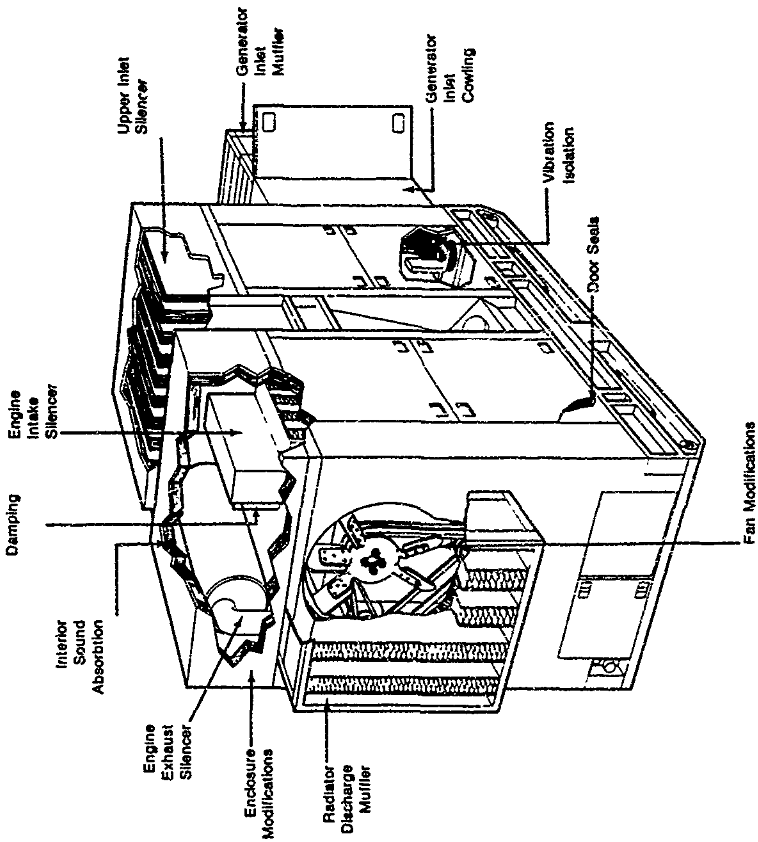



FIG. 6. SCHEMATIC DRAWING OF THE TREATMENTS INSTALLED IN THE FULLY TREATED SET.

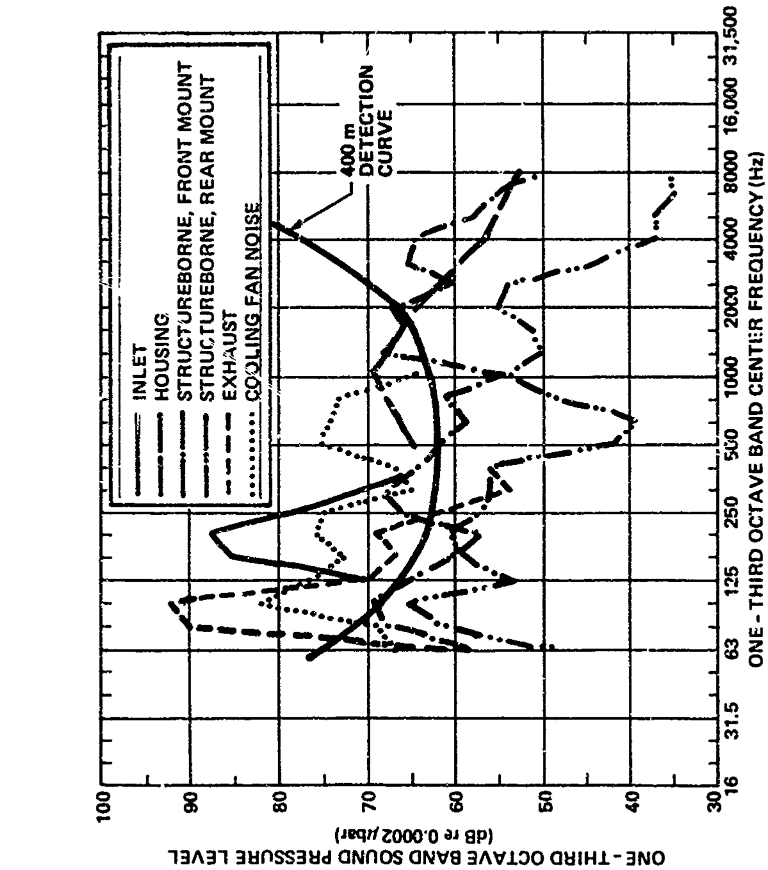



FIG. 7. SOURCE DIAGNOSIS FOR THE 30 KW DIESEL GENERATOR SET.

## 2.1 Exhaust and Intake Silencers

The noise from the diesel engine combustion air intake and the noise from the diesel engine combustion exhaust were controlled with reactive type silencers. The silencers were designed and constructed by Nelson Muffler, Stoughton, WI, according to specifications developed by BBN Laboratories Inc. Specifications were established on both noise reduction and back pressure. The required reductions in exhaust and intake noise were derived from the diagnostic measurements shown in Fig. 7. The required reductions were estimated by taking the difference between the measured exhaust and intake source levels, subtracting the levels associated with the 400 meter detection criterion and adding 6 dB to allow for the presence of other sources. Back pressure specifications were set by the requirements of the engine, a 6 cylinder, 298 cu. in., 1800 RPM, naturally aspirated, four stroke per cycle diesel engine, manufactured by White Engines, Inc., Hercules Engine Division. Insertion loss specifications and the performance of the resulting silencers are shown in Figs. 8 and 9. Sketches showing the overall dimensions of the two silencers and some details of the internal structure of the intake silencer are shown in Figs. 10 and 11.

The two silencers are currently carried by Nelson Industries, Inc. under part numbers

- air intake silencer Nelson Part No. 91469-A
- exhaust muffler Nelson Part No. 20212-N

Both silencers were designed to be mounted above the diesel engine as illustrated in Fig. 6. The exhaust silencer replaces a somewhat smaller unit and mounts similarly to the engine. Provision was made, however, to raise the muffler about 5 in. above the engine to reduce the restriction to the flow of cooling air as discussed more fully in Sec. 2.2.

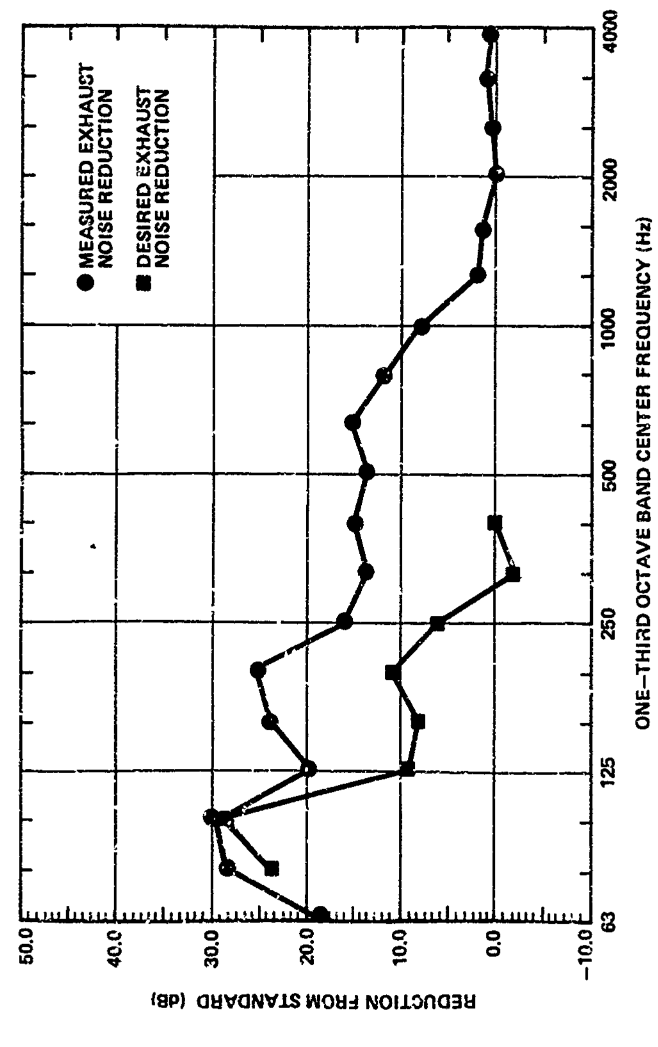



FIG. 8. EXHAUST SILENCER ACOUSTIC SPECIFICATION.

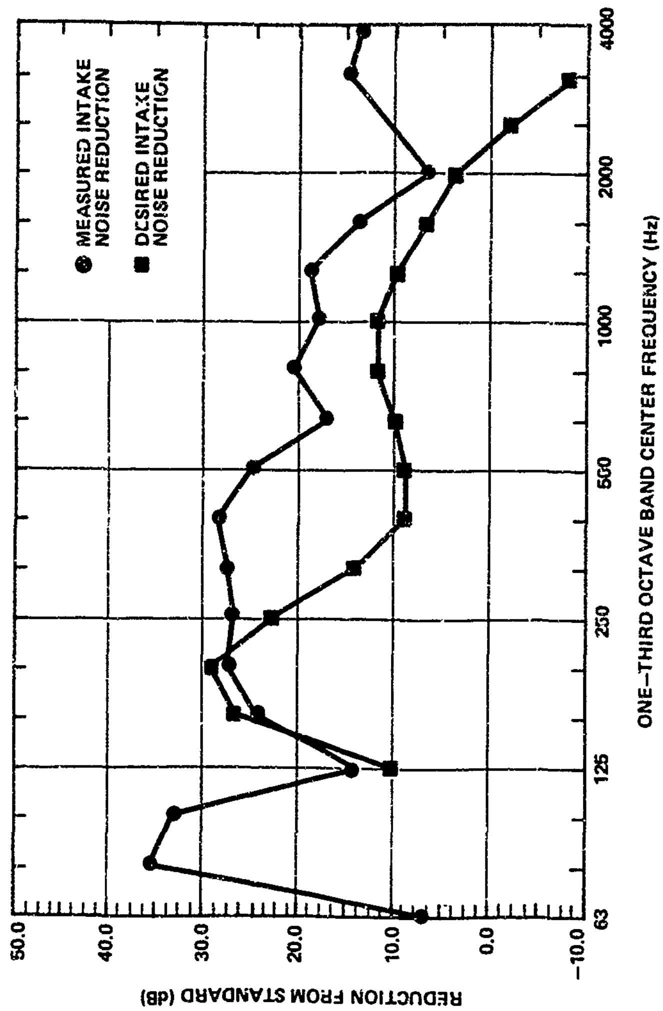



FIG. 9. INTAKE SILENCER ACOUSTIC SPECIFICATION.

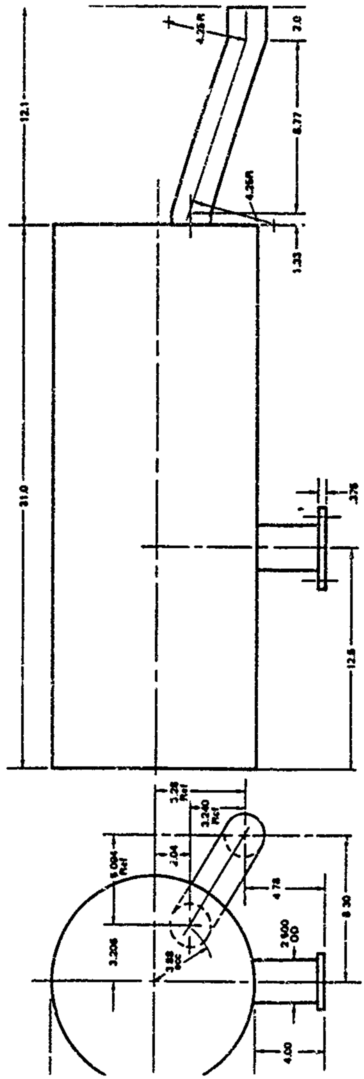



FIG. 10. THE EXHAUST SILENCER.

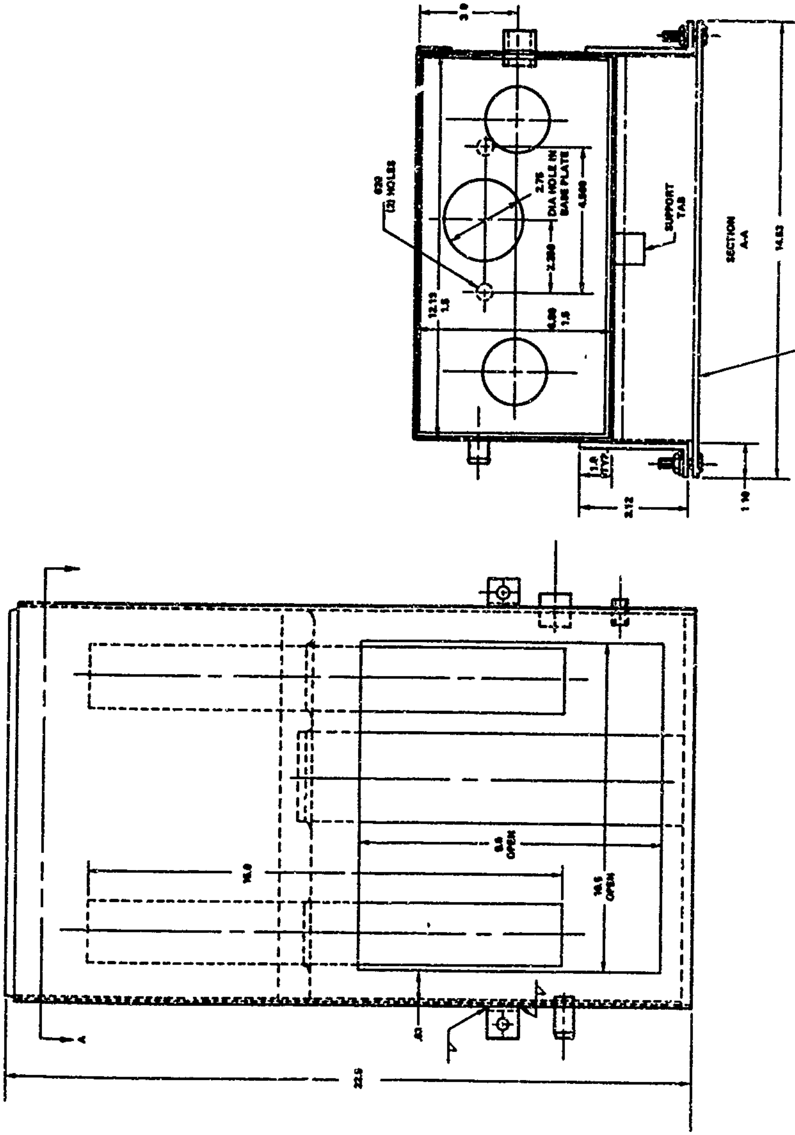



FIG. 11. THE INTAKE SILENCER.

The intake silencer replaces a small inlet air box that holds the intake air filter element. The new silencer is designed to accept this same filter element to simplify parts stocking and maintenance. Figure 12 shows the partially assembled prototype generator set as viewed from the control panel end of the set with the top housing cover removed. Just above the control panel and to the right the rear of the cylindrically shaped exhaust silencer can be seen. Just to the left of the exhaust muffler is the tall, rectangular intake silencer. Figure 13 shows another view of the the intake silencer as seen through the housing access door on the engine intake side, illustrating the installation of the original air filter element on the new silencer. Finally to prevent the impingement of exhaust gases on

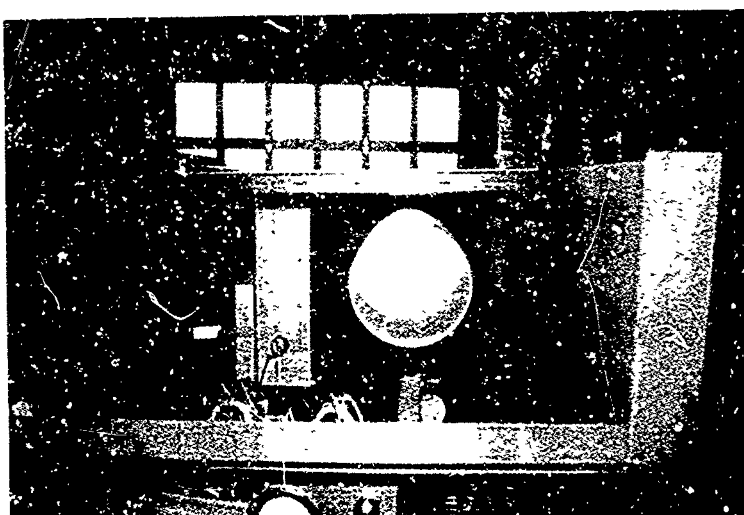


FIG. 12. VIEW OF THE PARTIALLY ASSEMBLED PROTOTYPE GENERATOR FROM THE CONTROL PANEL END SHOWING THE EXHAUST AND INTAKE SILENCERS.

FIG. 13. VIEW THROUGH THE ACCESS DOOR OF THE HOUSING SHOWING THE INTAKE SILENCER WITH THE STANDARD AIR CLEANER INSTALLED.

the metal parts of the set that would increase IR emissions, a diverter nozzle was installed at the outlet of the exhaust pipe as shown in Fig. 14.

## 2.2 Cooling Fan

Along with the engine exhaust and intake the cooling fan is one of the three noisiest sources on the 30 KW diesel generator. It clearly had to be treated if significant noise reduction was to be achieved. It was initially decided to try a two step approach. First, we would determine all the noise reduction that could be achieved through speed reduction while maintaining the requisite air flow. If that noise reduction were determined to be insufficient, we would then explore the use of more exotic fan designs.

FIG. 14. THE DIVERTER NOZZLE AT THE END OF THE EXHAUST PIPE TO PREVENT HOT GAS IMPINGEMENT ON THE SET.

Fortunately, we found that we were able to reduce the fan speed by nearly 30% while maintaining the airflow to within a few percent of its original value by appropriately modifying the housing to reduce the flow resistance for the cooling air.

Because fan noise is extremely sensitive to fan speed, the reduction in fan noise due to the reduced fan speed in conjunction with other housing treatments such as absorption and the use of parallel baffle silencers was sufficient to reduce the fan noise to the levels required without the use of more exotic fan designs.

### 2.2.1 Air Flow

We began with a series of measurements of air flow through the housing of the generator set. For these tests we used two pre-prototype configurations. Pre-prototype configuration 1 which is shown in Fig. 15 was an early configuration that reflected an early design concept. Although this concept was eventually changed the data obtained with this first pre-prototype provided us with useful guidance in later stages of the design. Pre-prototype configuration 2 is shown in Fig. 16. This pre-prototype more closely modeled the final configuration of the fully treated generator set. In fact pre-prototype configuration 2 had a number of treatments installed in final form. These included:

- engine exhaust muffler
- engine intake silencer
- vibration isolation
- modified cooling fan drive.

The raised roof of the housing, the three parallel baffle silencers, and the housing interior absorption were all simulated with plywood and glass fiber mat. Improved door seals were simulated by taping the doors shut to seal all leaks. Fan guards were removed. The cooling fan drive mentioned above was a special drive arrangement that allowed the fan and water pump to be run at different speeds. In this manner the water pump could be run at normal speed while the cooling fan speed was reduced as

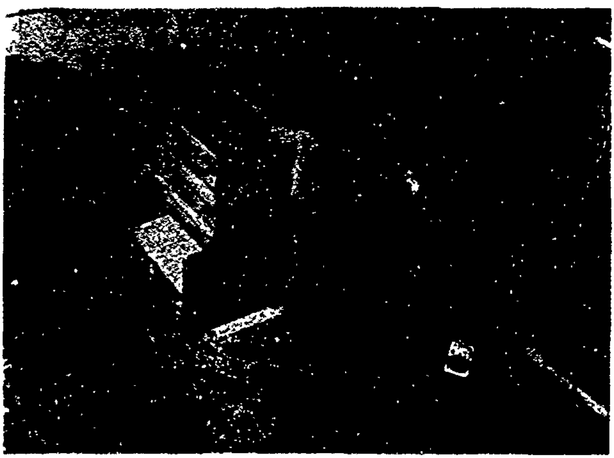
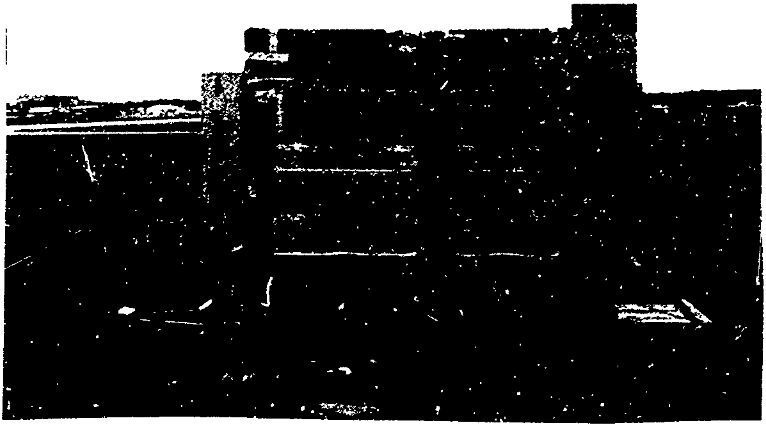


FIG. 15. TEST SET-UP FOR AIR FLOW TESTS USING PRE-PROTOTYPE CONFIGURATION 1.



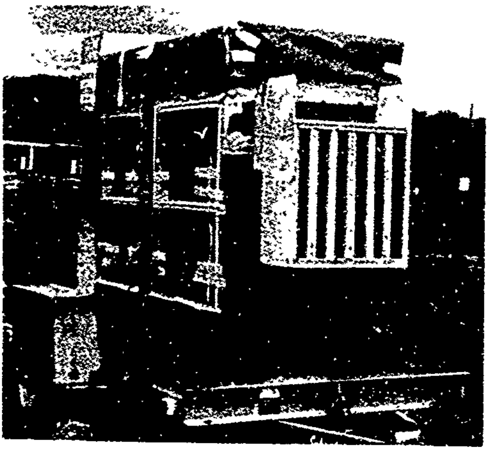


FIG. 16. PRE-PROTOTYPE CONFIGURATION 2, A LATER PRE-PROTOTYPE TEST CONFIGURATION.

required. Details of the fan drive arrangement are discussed in Sec 2.2.5.

The set up for performing the initial air flow test on pre-prototype configuration 1 is shown in Fig. 15. As shown in the figure the untreated generator was connected to an 8 ft. long plywood duct, the cross section of which matched the cross section of the cooling air discharge opening in the housing at the radiator end of the set. The cross sectional area of the duct was 4.17 sq. ft.

The purpose of the long tunnel was to allow the turbulence in the discharge air flow to decay away before attempting to measure the air velocity. Using a pitot tube in the tunnel at 7.5 ft from the face of the generator radiator opening, we measured the air flow velocity at 25 points on a plane perpendicular to the axis of the tunnel to obtain a measure of the volume velocity of the air leaving the set. Pressure drop through the tunnel was measured and found to be less than 0.1 in of water.

Although we operated the generator to turn the fan for most of the air flow tests, we also had a variable speed electric motor, shown to the right of the set in Fig. 15, to turn the fan independently of the engine when necessary. That independent drive was especially useful in the noise tests when a quiet fan drive was necessary.

The doors of the set were replaced with sheets of clear acrylic plastic to allow flow visualization studies to be carried out using a smoke generator. The flow visualization studies were especially helpful in identifying the primary paths for air flow through the housing and in determining those elements in the flow path that were especially restrictive to the movement of cooling air. For example we found that when cooling air enters the cooling air inlet opening at the the control panel end of the set, it flows up over the generator and engine and is confined primarily to the right or exhaust muffler side of the housing. Flow to the

left is virtually negligible due to various electronic equipment and boxes that restrict air flowing to that side of the housing. Flow beneath the generator is similarly restricted by the fuel tank and generator mounting beam.

Once we discovered that the primary path for cooling air flow was over the top of the engine and generator and confined to the right half of the housing, we focused our attention on elements in that flow path. We found, for example that the fan guards (metal shields in the vicinity of the cooling fan that restrict access to the blades to prevent personal injury) were a greater restriction to air flow than their size would suggest. Similarly we found that the original exhaust muffler presented a significant flow restriction, leading to the decision to raise the replacement muffler well above the engine to clear a passage for cooling air. Although these results were primarily qualitative in nature, they did help to focus the quantitative studies of air flow that were to follow.

The results of the air flow measurements are presented in Table 1. The results indicate that the fan guards need to be modified to minimize flow restrictions, that an auxiliary air inlet needs to be provided and that the air inlet behind the generator and below the control panel needs to be opened up to the greatest extent possible. With these modifications made to the housing, it was possible to reduce the fan speed by 20% and still maintain the original cooling air flow through the set.

Since in some applications personnel climb up on the roof and use it for storage of equipment, pre-prototype configuration 1, shown in Fig. 15 was redesigned to incorporate a flat roof. This second pre-prototype generator configuration shown in Fig. 16 was then fabricated and tested for air flow. This later configuration had the added advantage that by raising the roof of the housing above the engine, space was made for the enlarged intake silencer and enlarged exhaust muffler. When this prototype was constructed provision was made to carry out a set of air

TABLE 1. MEASUREMENTS OF COOLING AIR FLOW THROUGH THE 30 KW GENERATOR SET.

| | Description | Air Flow [CFM] | Percent Change |
|---|---|---|---|
| 1. | Baseline (loaded) | 4118 | 0 |
| 2. | Baseline (unloaded) | 4087 | -1.3 |
| 3. | Remove Fan Guards | 4485 | +8.9 |
| 4. | Inlet grill Removed (no fan guards) | 4757 | +15.5 |
| 5. | Open Auxiliary Air Inlet (no fan guards) | 5665 | +37.6 |
| 6. | All doors open (no fan guards) | 6255 | +51.9 |
| 7. | Same as 5 with inlet silencer over generator opening. | 5374 | +30.5 |
| 8. | Same as 7 with auxiliary air inlet silencer | 4258 | +3.4 |
| 9. | Same as 8 with radiator discharge silencer | 4169 | +1.2 |
| 10. | Same as 9 with inlet grill removed and inlet opened to maximum extent possible | 5217 | +26.7 |
| 11. | Same as 10 with fan speed reduced 10%. | 4691 | +13.9 |
| 12. | Same as 10 with fan speed reduced 20%. | 4110 | 0 |

flow measurements using the same test procedure as was used for pre-prototype configuration 1. In this case however the modified fan drive was installed on the set, and we ran a series of tests using various size pulleys on the engine to drive the fan while keeping the water pump running at its normal speed of 2000 rpm. Using standard size drive pulleys we obtained fan speeds of 1450

rpm, 1510 rpm and 1670 rpm, or 73%, 76% and 84% of the normal fan speed of 2000 rpm. Air flow measurements were made on pre-prototype configuration 2 with these three fan speeds. The results are presented in Table 2. All measurements were performed at an ambient temperature of 74 degrees Fahrenheit and the accuracy of the measurements is approximately ± 2 to 3%. The table shows that the air flow achieved for each of the three fan speeds was very close to the air flow through the untreated set even though fan speeds were considerably reduced.

**TABLE 2. AIR FLOW MEASUREMENTS WITH THE PRE-PROTOTYPE CONFIGURATION OF FIGURE 16.**

| Fan Speed [RPM] | Percent of Untreated Set RPM | Air Flow [CFM] | Percent Change in CFM from Untreated Set |
|---|---|---|---|
| 2000 | 0 | 4087 | 0.0 |
| 1670 | 84 | 4124 | +1.0 |
| 1510 | 76 | 3911 | -4.3 |
| 1450 | 73 | 3870 | -5.3 |

### 2.2.2 Cooling System Tests

Although the air flow test conclusively demonstrated that the fan speed could be considerably reduced while still maintaining the required air flow through the set, we also ran a number of cooling system tests to verify the cooling system performance. These tests were run in a room with engine exhaust gases vented to the outside. Generator set cooling air was allowed to recirculate in the room as well as heated air from a resistive load cell also operated in the test chamber. In this way the ambient temperature in the room could be raised considerably and eventually stabilized.

The modified fan drive discussed above was installed in pre-prototype configuration 1, and we tested the set in a chamber at an ambient temperature approaching 100°F. For these tests we selected the fan pulley that would provide us with 73% of standard fan speed. The set was fitted with thermocouples to enable us to measure radiator top tank temperature, engine oil temperature, room ambient temperature, housing interior temperature, engine intake temperature, generator cooling air outlet temperature and the average temperature of the air entering the cooling air inlet at the generator end of the set. This last measurement was accomplished with an array of eight thermocouples in the cooling air inlet below the control panel.

Throughout the test the generator was run at full load with the thermostat held fully open. The temperature data in Fig. 17 show that the difference between top tank coolant temperature and ambient temperature (room temperature or inlet cooling air temperature) was at worst about 79°F. At an ambient temperature of 125°F, the highest specified operating temperature for the set at sea level, the anticipated radiator top tank temperature would be expected to be 204°F well below the 217°F shut down temperature of the generator set.

A later test with pre-prototype configuration 2 (see Fig. 16), a configuration that more closely simulates the final configuration gave slightly different results. The modified fan drive was installed with the cooling fan operating at 73% of full speed. The resulting temperatures in the set are shown in Fig. 18. During this test we were able to obtain ambient temperatures approaching 125°F in the test chamber. Although we were unable to fully stabilize the chamber temperature, the results indicate that the difference between top tank radiator coolant temperature and ambient (room or cooling air inlet) temperature had stabilized at 92°F to 94°F. At 125°F ambient that implies a coolant temperature of 217°F to 219°F which is right at the temperature limit for the set. In this particular test the set ran quite

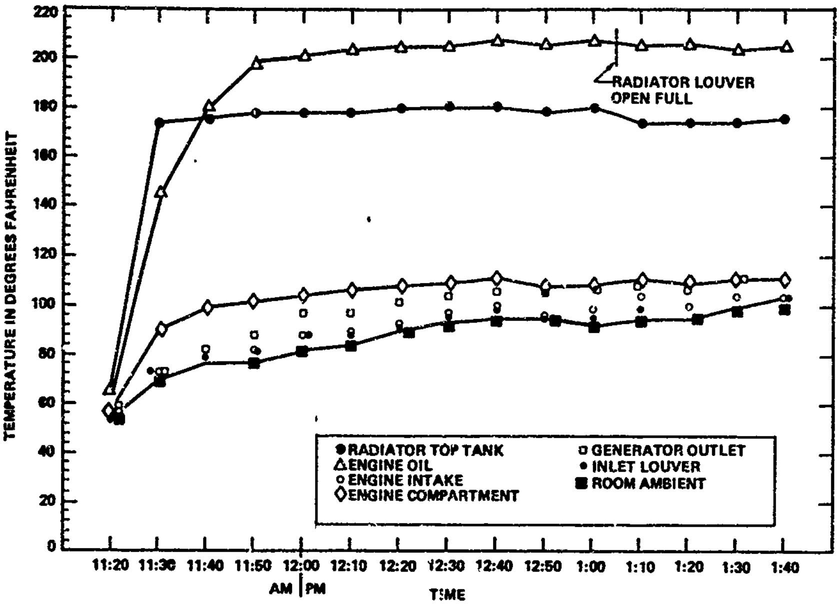



FIG. 17. COOLING SYSTEM PERFORMANCE TESTS WITH PRE-PROTOTYPE CONFIGURATION 1.

well at 124°F ambient. However, when we attempted to slow the fan below 73% (1450 rpm), the coolant over temperature interlock shut the set down, confirming the 1450 rpm was the minimum allowable fan speed in this configuration.

The above tests demonstrated that the slower cooling fan would provide adequate air flow and cooling capacity provided the set were modified to reduce the air flow restriction through the housing. In the next section we discuss the noise reduction associated with the fan speed reduction and associated housing modifications.

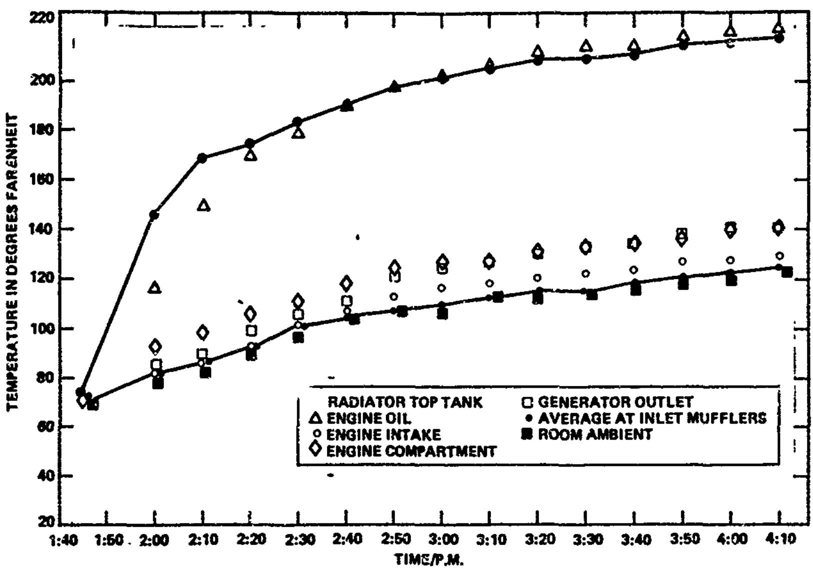



FIG. 18. COOLING SYSTEM PERFORMANCE TESTS WITH PRE-PROTOTYPE CONFIGURATION 2.

### 2.2.3 Noise Reduction

To measure the effects of various treatments on fan noise the generator was set up on the same trailer as shown in Fig. 5 in a large parking lot. With the radiator louvers locked open the fan was driven with the variable speed electric motor described previously, and the noise was measured at a number of points on a 25 ft (7.5 meter) circle around the generator at a height of 5 ft 6 in, the same height as the centerline of the fan. Figure 19 shows the overall A-weighted sound level as a function of position around the generator set with just the fan running. Note that the noise measured in the same configuration with the fan removed was found to be at least 20 dB lower than with the fan attached, indicating that we were measuring only fan

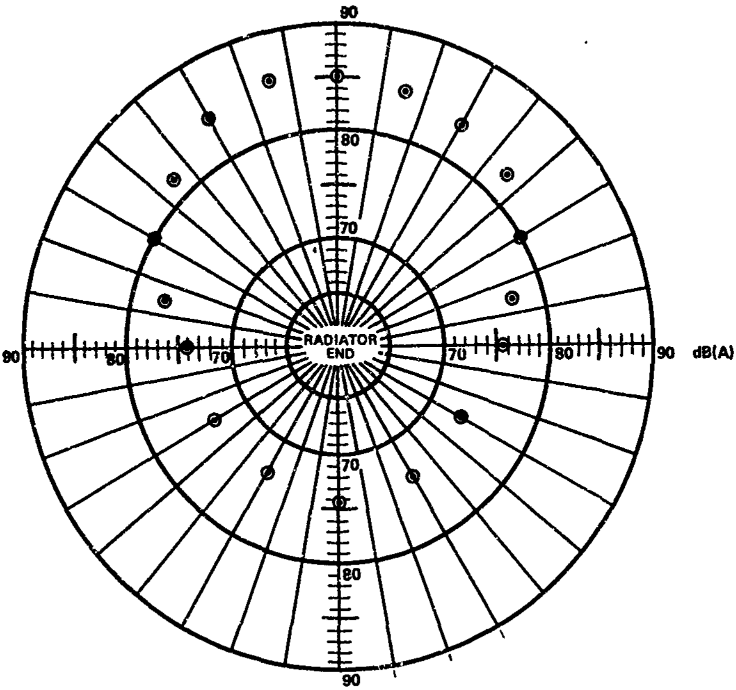



FIG. 19. THE OVERALL A-WEIGHTED SOUND LEVEL DUE TO THE COOLING FAN AS A FUNCTION OF POSITION AROUND THE GENERATOR.

noise. As the figure shows, the noise is radiated primarily from the radiator end of the set as one would expect.

Figure 20 shows the change in the overall A-weighted sound level with various changes to the set. Removing the fan guards not only improves the air flow through the set, but, as the figure shows, it also reduces the fan noise by over 3 dBA. In addition with the fan guards reinstalled fan speed reductions of

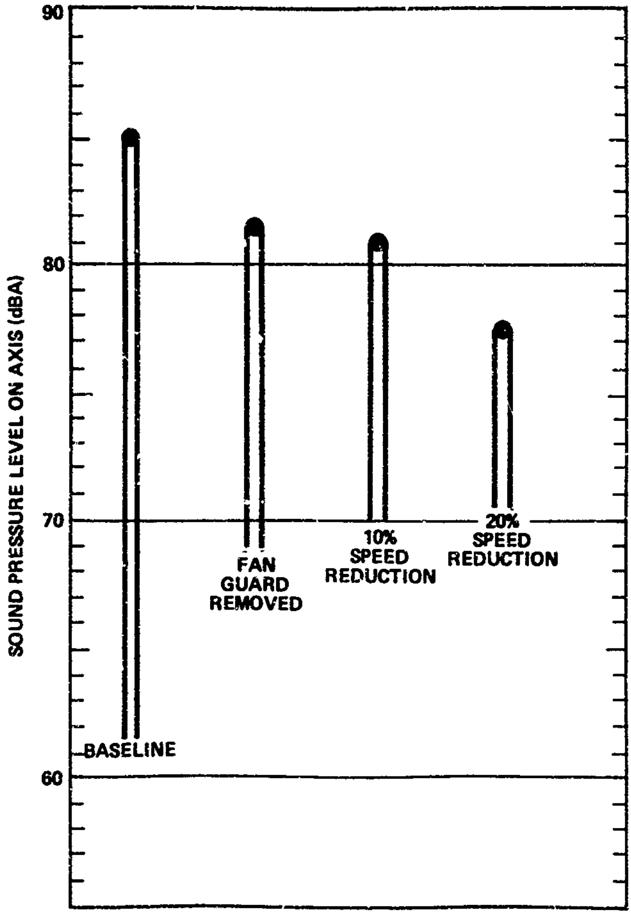



FIG. 20. THE CHANGE IN THE OVERALL A-WEIGHTED SOUND LEVEL FROM THE COOLING FAN WITH VARIOUS CHANGES TO THE SET.

10% and 20% were found to result in fan noise reductions of 4 dBA and 7.5 dBA, respectively.

Figure 21 shows the one third octave band spectrum of fan noise for the fan operating at full speed and at 80% of full speed. These data have been corrected to reflect operation on grass rather than asphalt since it is the former surface for which the 400 meter detection criterion was developed. The correction is shown in Fig. 22, and was obtained from the comparison of noise measurements of the untreated generator (on a trailer) on an asphalt parking lot with similar measurements of the same generator on a grassy field. Also shown in Fig. 21 are the 400 meter and 500 meter detection criteria. The noise from the fan when run at 1600 RPM (80% of full speed) exceeds the 500 m criterion by a small margin but exceeds the 400 m criterion by

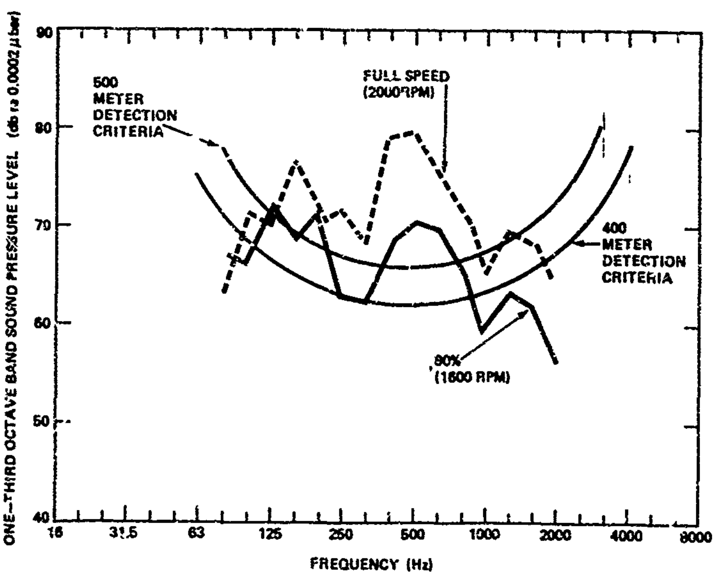



FIG. 21. FAN NOISE SPECTRUM CORRECTED FOR OPERATION ON GRASS.

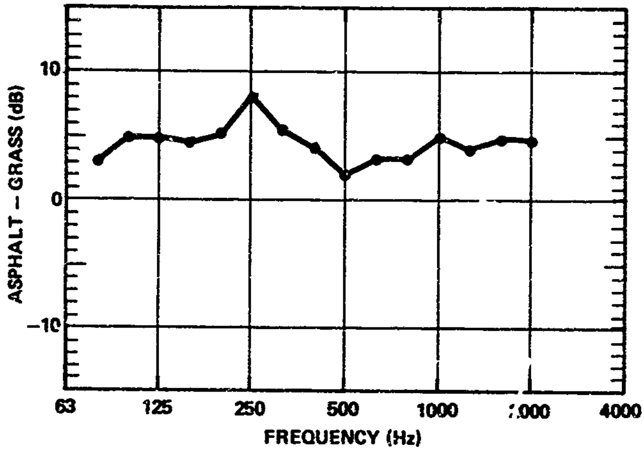



FIG. 22. THE ASPHALT TO GRASS CORRECTION.

over 9 dB. There are, however, a number of factors that will reduce the fan noise below the levels shown in Fig. 21.

First, absorption added to the interior of the housing would be expected to reduce the noise from the fan by 3 to 5 dB, based on phase 1 measurements [1]. In addition, running the fan at 73% of full speed instead of 80% will provide on the order of 2.5 dB of additional noise reduction, and the removal of the fan guards can be expected to further reduce the noise by up to 3 dB. Lastly, the parallel baffle silencer over the radiator opening will provide from 3 to 20 dB of noise reduction above 500 Hz. In short although the measured noise from the low speed fan in the otherwise untreated generator set exceeded the 400 and 500 meter detection criteria, we were confident that the other housing noise control treatments would bring the fan noise below the criterion, eliminating the need for any exotic fan designs.

### 2.2.4 Housing Modifications

The modifications to the fan guards are shown in Fig. 23. In the treated set the original solid sheet metal guards have been replaced by a metal screen to reduce the flow restriction.

The changes to the air inlet behind the generator and below the control panel are shown in Fig. 24. The narrow doors on the original set, shown on the left, have been removed and replaced with doors that span the full width of the set as shown on the prototype configuration at the right of Fig. 24. The restrictive louvers on the inlet opening have been removed and and the solid panels to the right and left of the louvers have been removed and replaced with an open wire mesh. Finally the utility receptacle has been moved to the right side of the set just forward of the full width doors, and the paralleling receptacles have been moved to the control panel.

The configuration for the auxiliary air inlet above the control panel is shown in Fig. 25. The inlet is approximately 12 in. high and spans the full width of the set. It is equipped with a parallel baffle silencer as are the cooling air inlet at the control panel end of the set and the cooling air discharge at the radiator end of the set. All three parallel baffle silencers will be discussed in detail in Sec. 2.3.

### 2.2.5 Fan Drive Modifications

The tests described above indicated that the air flow could be maintained through the set even with a slower running fan. Based on that result one would expect that if water pump speed were kept the same, then the set would cool itself as well as before modification. We, therefore, modified the water pump drive arrangement to allow the cooling fan and water pump to spin at different speeds. In the original arrangement the fan was bolted to a V-belt pulley that was in turn bolted to the water pump shaft. That pulley was driven from a V-belt pulley mounted

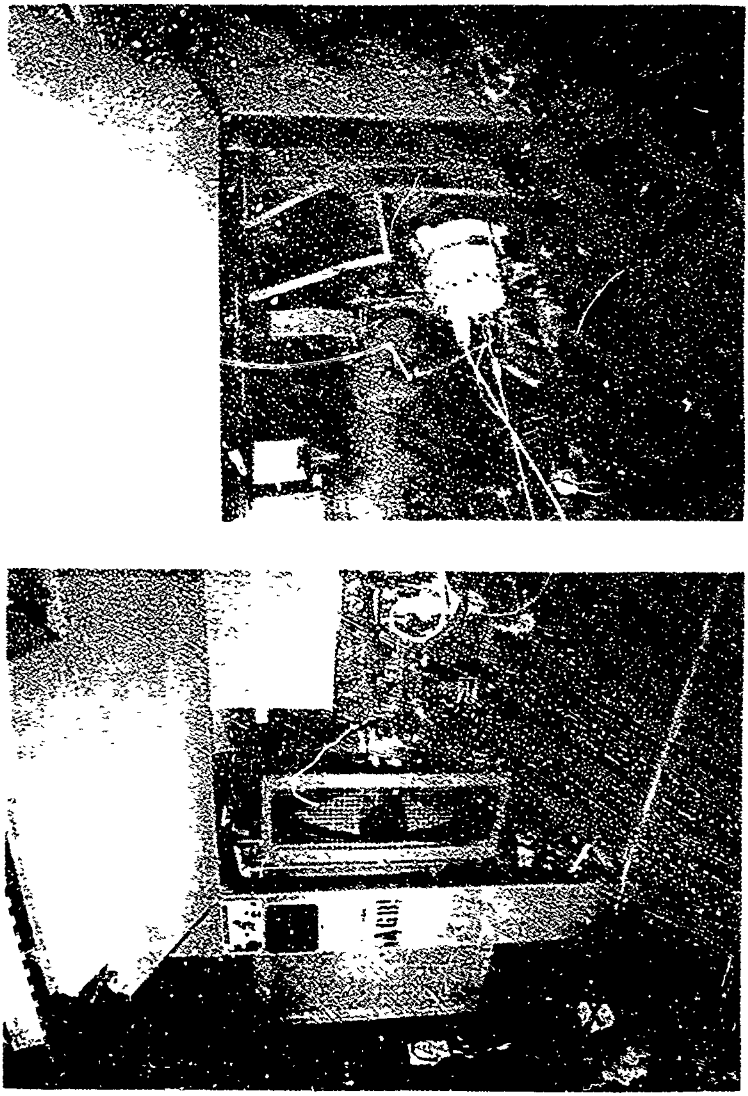
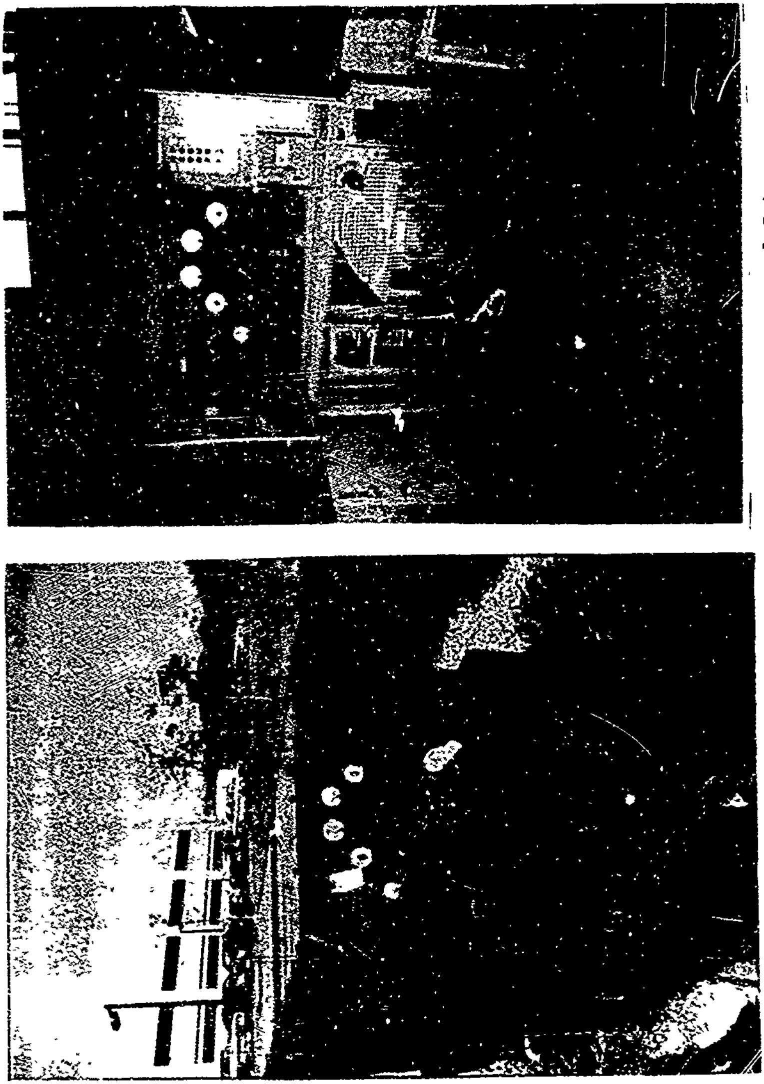


FIG. 23. MODIFIED FAN GUARDS ON THE FULLY TREATED SET.



(a) Untreated Set (b) Treated Set

FIG. 24. MODIFICATIONS TO GENERATOR AIR INLET ON THE FULLY TREATED SET.

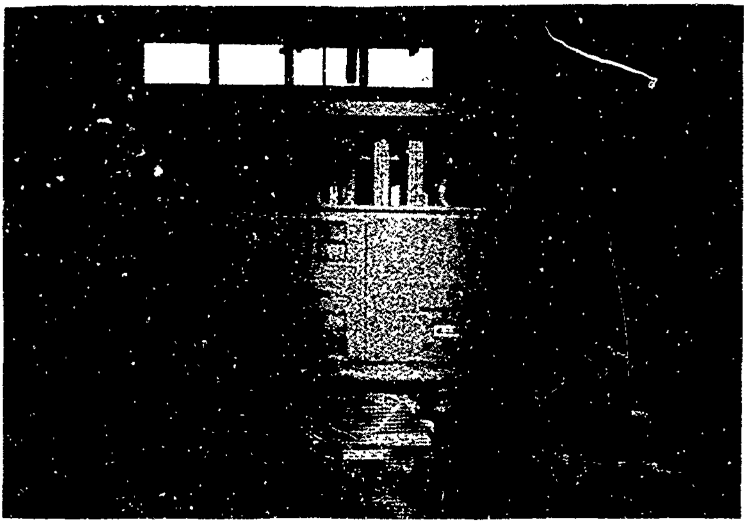


FIG. 25. THE AUXILIARY AIR INLET ABOVE THE CONTROL PANEL.

to the engine crank shaft on the front of the engine. In the modified arrangement a second V-belt pulley to which the fan was attached was supported in a bearing and mounted to the original waterpump pulley. To drive this new fan pulley a second drive pulley was mounted in front of the original drive pulley on the engine crankshaft. By changing tne size of this new drive pulley, a range of fan speeds could be selected while maintaining the same waterpump speed. The modified fan drive arrangement is shown in Fig. 26.

## 2.3 Housing Airborne Noise Control

### 2.3.1 Sound absorptive treatment

As discussed above, sound absorptive treatment applied to the inter'or walls of the housing had been found in previous

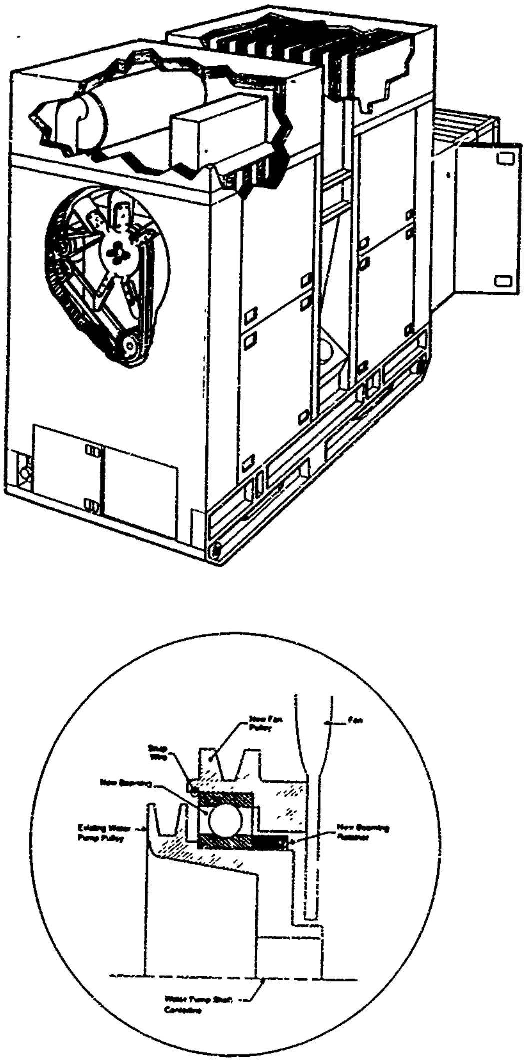



FIG. 26. MODIFIED FAN DRIVE.

measurements to provide 3 to 5 dB of noise reduction for sources of airborne noise in the housing interior. Consequently, we planned to apply as much absorptive material to the housing interior as practical. We did not, however, apply any treatments below the engine. In that location grease and oil contamination of the absorptive material would be expected to rapidly deteriorate its acoustic performance, resulting in some increase in the noise from the set with time. Although the sound absorptive treatment that we used is readily cleanable, we felt that treatment placed under the engine would not be cleaned as often as necessary. We also limited the application of absorption to surfaces that were sufficiently large to justify the cost of fabrication and installation.

The absorptive treatment design used throughout the generator set is shown in Fig. 27. Various thicknesses of glass fiber mat are wrapped in 0.5 mil polyester film. A coarse plastic

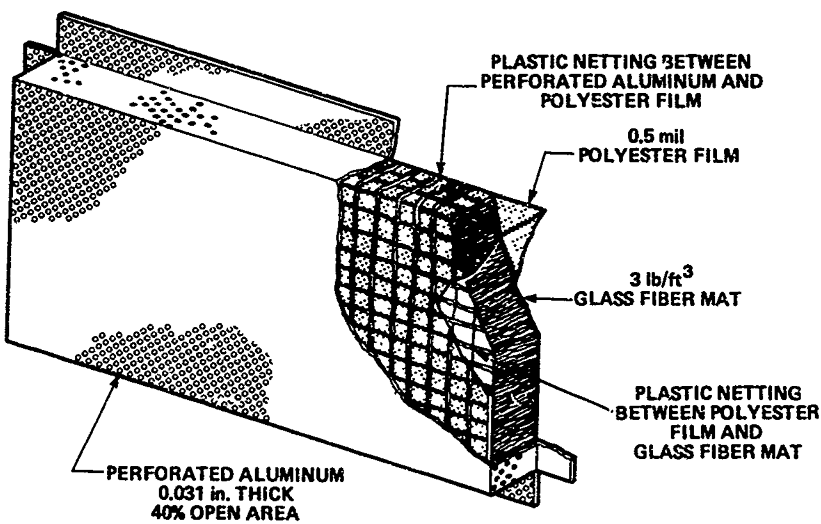



FIG. 27. ABSORPTIVE TREATMENT.

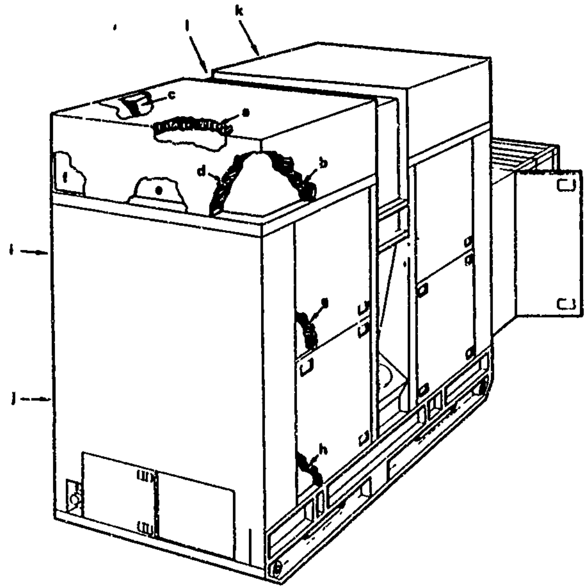
netting is placed between the polyester film and glass fiber mat to minimize the degradation in the absorption due to the presence of the film. The purpose of the film is to prevent the contamination of the glass fiber mat (by dirt, grease, oil, diesel fuel, etc.) that would degrade the acoustic performance of the material or present a flammability hazard. In addition the polyester film which totally enclosed the glass fiber mat is impervious to moisture and cleaning fluids, allowing the absorptive treatment to be cleaned as necessary.

To mechanically protect the treatment it is covered with 1/32 in. perforated aluminum. The same coarse plastic netting used between the polyester film and the glass fiber mat is used between the perforated aluminum and the polyester film to prevent degradation of the acoustic performance of the absorption.

The locations and thicknesses of the absorptive treatments in the housing are shown in Fig. 28. Absorptive treatment covered the interior surfaces of three of the four doors and the roof and valence area with thicknesses ranging from 1 to 4 in. A photograph of the fully treated set with the doors open to show the absorptive treatment is shown in Fig. 29.

### 2.3.2 Parallel baffle silencers

To control the emission of airborne noise from the housing through the large openings that allow cooling air to enter and leave the housing, three parallel baffle silencers were used. Silencers of this type consist of parallel rows of absorptive treatment separated by a few inches. Figure 30 shows a schematic drawing of a typical parallel baffle silencer and the measured insertion loss as a function of frequency. As the figure shows this type of silencer perform best at frequencies above 500 Hz. Below that frequency the insertion loss is only a few dB.




| ABSORPTION THICKNESS | |
|---|---|
| Location | Thickness (In.) |
| a | 4 |
| b | 3 |
| c | 3 |
| d | 4 |
| e | 2 |
| f | 4 |
| g | 4 |
| h | 2 |
| i | 1 |
| j | 3 |
| k | 4 |
| l | 2 |

FIG. 28. ACOUSTIC ABSORPTION ON THE HOUSING INTERIOR.

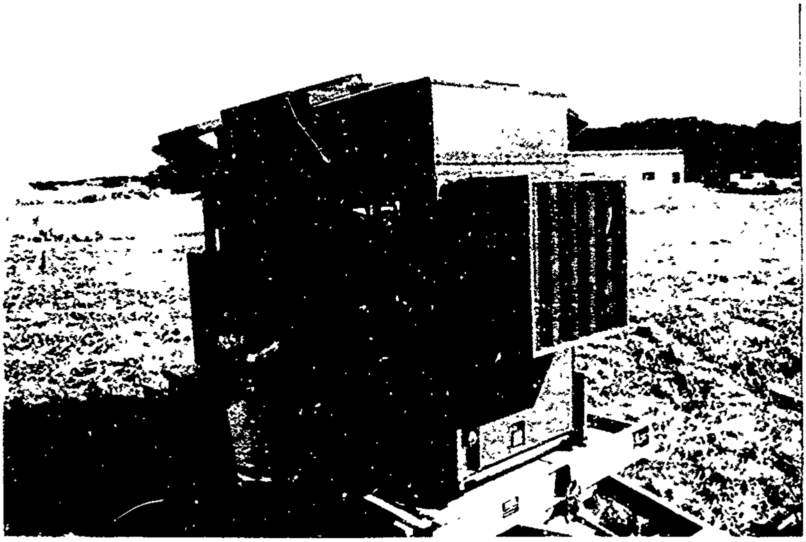


FIG. 29. ABSORPTIVE TREATMENT APPLIED TO THE DOORS.

Parallel baffle silencers were used over the cooling air inlet aft of the generator opening to the housing and below the control panel; within the auxiliary air intake at the generator end of the set above the control panel; and over the cooling air discharge opening at the radiator end of the housing. The parallel baffles were fabricated of absorptive material in essentially the same manner as the absorptive treatment applied to the walls of the housing, described in Sec. 2.3.1. Figure 31 shows the silencer for the radiator discharge opening by itself and being installed on the set. The silencer is removable and can be installed and clipped in place over the radiator opening by one person. The silencer for the inlet at the generator end of the set below the control panel is shown in Fig. 32, sitting by itself and being installed on the generator set. This silencer

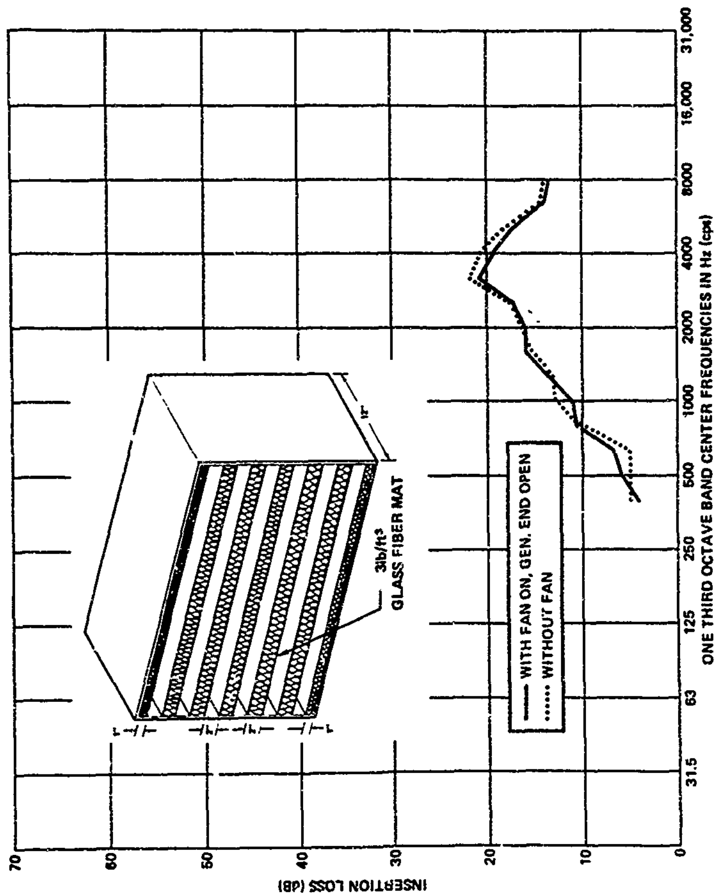



FIG. 30. A TYPICAL PARALLEL BAFFLE SILENCER AND ITS ACOUSTIC PERFORMANCE.

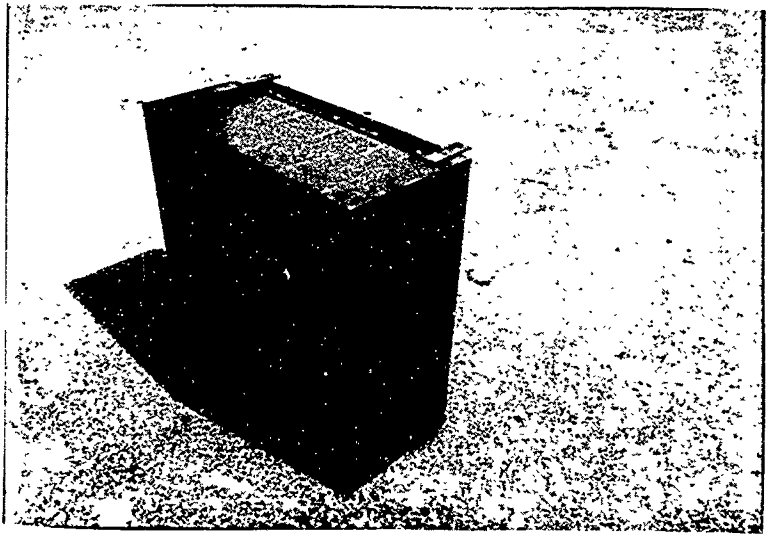



FIG. 31. THE PARALLEL BAFFLE SILENCER FOR THE RADIATOR COOLING AIR DISCHARGE OPENING TO THE HOUSING.

FIG. 32. THE PARALLEL BAFFLE SILENCER FOR THE COOLING AIR INLET OPENING AT THE GENERATOR END OF THE HOUSING.

comes in two parts that clip together and in turn clip to the generator set. The silencer was separated in this way so as to keep its weight down and thereby allow it to be easily handled by one person. The silencer in the auxiliary cooling air inlet is permanently installed. A drawing of it is shown in Fig. 33. Figure 34 shows the silencer installed in the generator set. The auxiliary air inlet silencer is equipped with a rain gutter and drain to prevent entry of water into the set.

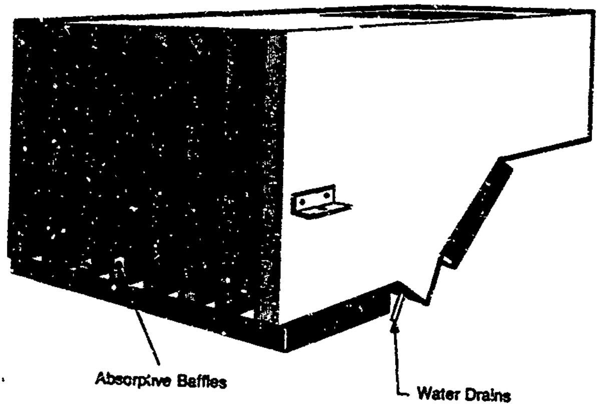



FIG. 33. DRAWING OF THE PARALLEL BAFFLE SILENCER FOR THE AUXILIARY COOLING AIR INLET OPENING TO THE HOUSING.

### 2.3.3 Door seals

The phase 1 measurements indicated that improved door seals were not necessary on the generator set that was tested. However, because of set to set variability in the fits of the doors we elected to replace the seals with slightly thicker seals to make the doors fit more snugly and to provide a more positive seal no matter what irregularities might occur in door fabrication. The original seals were made of a foam rubber strip trapezoidal in cross section, that fit in a recess in the door

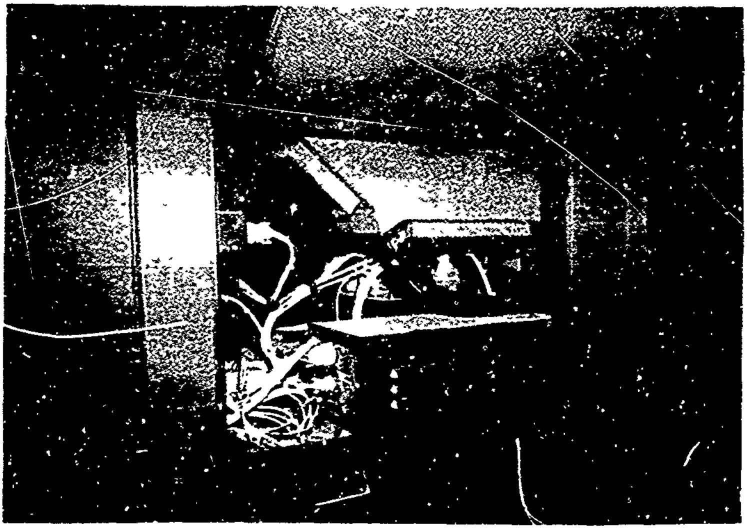


FIG. 34. THE PARALLEL BAFFLE SILENCER FOR THE AUXILIARY COOLING AIR INLET AS SEEN FROM THE BACK AND THE SIDE OF THE SET.

and mated with a raised edge on the housing. We simply replaced these strips with closed cell neoprene strips that were 1/8 in. thicker than the original seals.

### 2.3.4 Damping

There was minimal use of damping treatment on the quieted generator set. Early in the program it was noticed that the engine intake silencer and the right side (exhaust side) of the engine oil pan had lightly damped resonances between 150 Hz and 200 Hz. Because there is considerable excitation in that frequency range from the cooling fan, twice the engine firing frequency, and the fundamental engine intake frequency, we decided to apply damping treatment to those two engine components.

On the right hand side (engine exhaust side) of the oil pan we epoxied a 1/8 in layer of Soundcoat DIAD 606 damping material. This particular material is designed to have its peak loss factor at about 150°F. Consequently at the typical operating temperatures of the engine we obtained nearly maximum damping effect from the material.

We also epoxied this same material to the outside of the intake silencer on the side opposite the inlet air opening. Although DIAD 606 is not best suited to the anticipated operating temperature of the intake silencer, we felt it would perform adequately enough for our purposes.

## 2.4 Vibration Isolation

As originally configured the engine/generator in the 30 KW generator set was bolted directly to the mounting beams in the skid base of the housing with no vibration isolation as shown in Fig. 35. The measurements of phase 1 showed that vibration isolation would have to be employed in order to achieve the desired degree of noise reduction. Fortunately the mounting beams in the skid base are very stiff. Consequently the resilient mounts themselves could be fairly stiff and still provide the degree of isolation required.

In order to install the mounts without changing the engine location in the housing, some modification of the housing mounting beams was required. Figure 36 shows the installation of one of the mounts near the generator. The channels that originally supported the engine/generator were removed and the support beam drilled to allow for installation of the resilient mounts (Barry Controls Model 510-4). At the front under the engine the modifications were somewhat more difficult to carry out. The mounting beam had to be cut away as shown in Fig. 37, a mounting plate was welded to the top and the trunion mounting bracket was mounted to the beam as shown with two resilient mounts (Barry Controls Model 508-3).

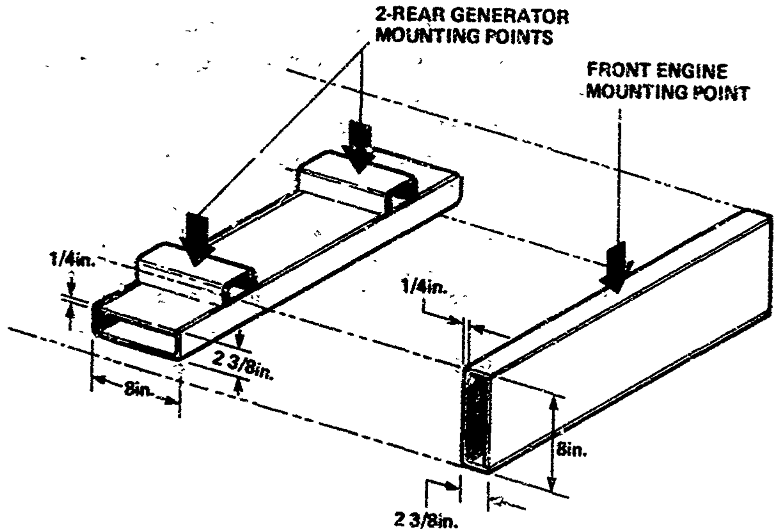



FIG. 35. ORIGINAL ENGINE/GENERATOR MOUNT CONFIGURATION.

The reduction in engine/generator mounting point vibration due to the installation of the resilient mounts is shown in Figs. 38 and 39. Although the pattern is quite complicated with limited vibration reduction at 125 Hz, 250 Hz and 500 Hz, especially at the forward mount beneath the engine, the reduction is substantial at the other frequencies, ranging from 10 to 30 dB. The reduction in vibration measured on the panels of the housing as shown in Fig. 40 shows a fairly constant 10 dB reduction in vibration throughout the frequency range of interest, except for 125 Hz where the vibration reduction is poor. The reason for the decrease in the vibration reduction of the mounts at 125 Hz is unknown although the presence of a resonance in the mounting system, involving the mass of the mounting beams oscillating in the side to side direction on the stiffness of the housing skid base, is a likely explanation.

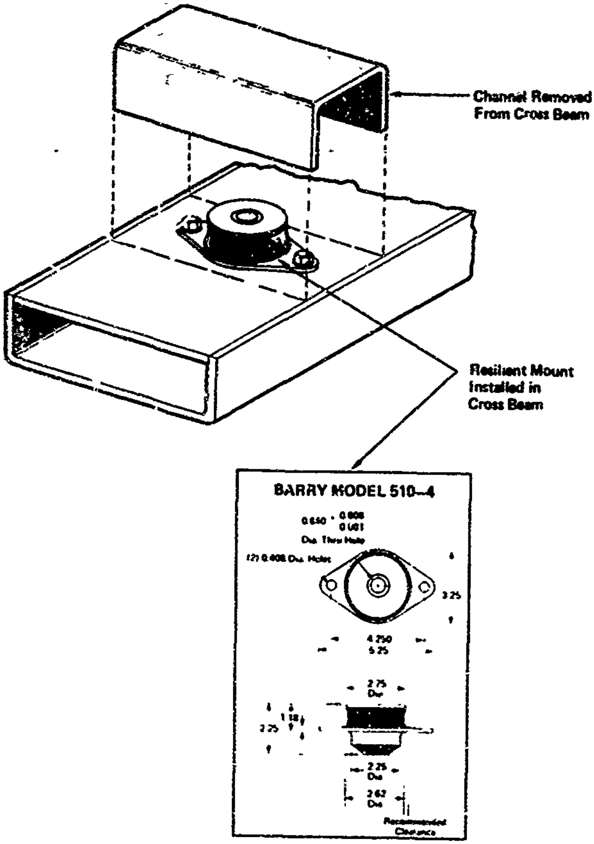



FIG. 36. MODIFIED REAR ENGINE/GENERATOR MOUNTS.

Except for the problem at 125 Hz the vibration reduction in Fig. 40 is more than adequate to eliminate structureborne noise as a significant contributor to generator set noise, and, in fact, as latter tests showed even the drop in vibration reduction at 125 Hz did not affect the overall generator acoustic performance.

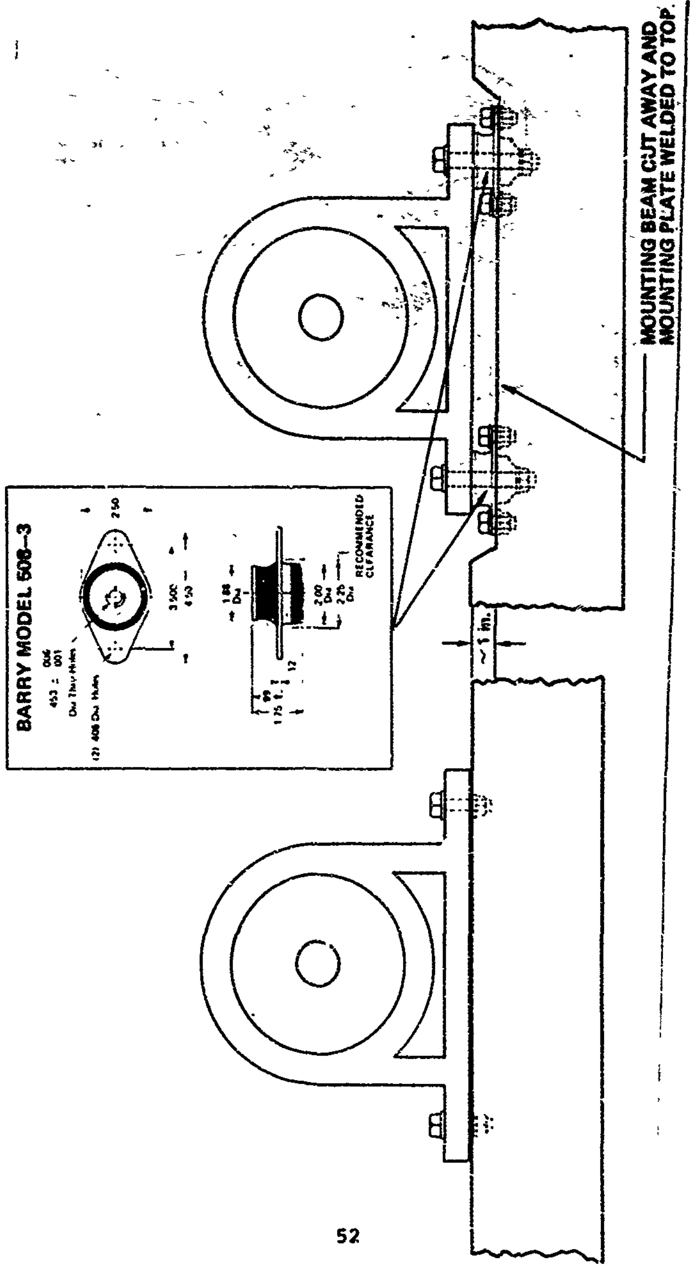



FIG. 37. MODIFIED FRONT ENGINE/GENERATOR MOUNTS.

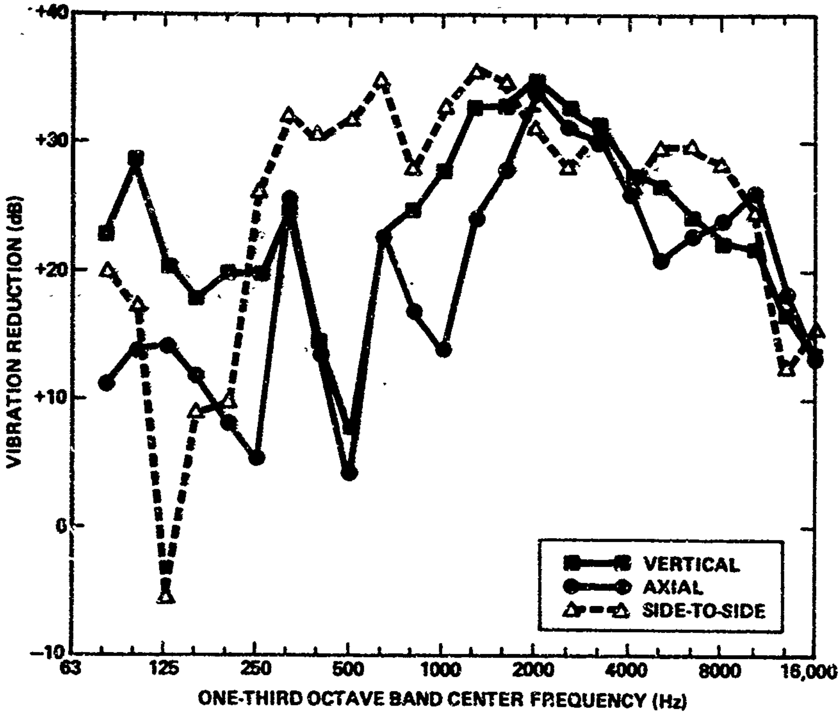



FIG. 38. REDUCTION IN ENGINE/GENERATOR MOUNTING POINT VIBRATION AT THE FORWARD MOUNT BENEATH THE ENGINE DUE TO INSTALLATION OF RESILIENT MOUNTS.

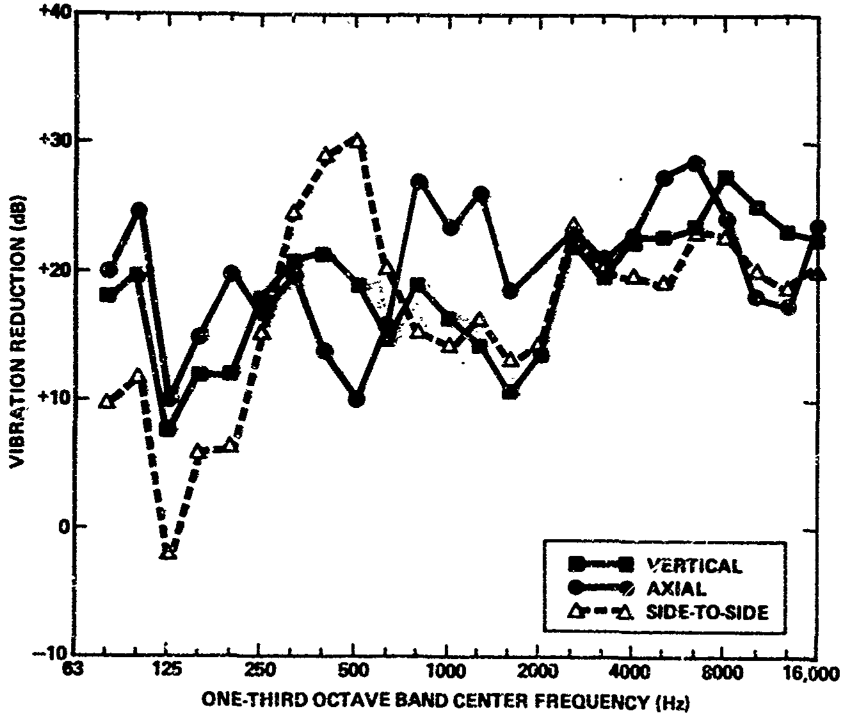



FIG. 39. REDUCTION IN ENGINE/GENERATOR MOUNTING POINT VIBRATION AT THE REAR MOUNTS BENEATH THE GENERATOR DUE TO THE INSTALLATION OF RESILIENT MOUNTS.

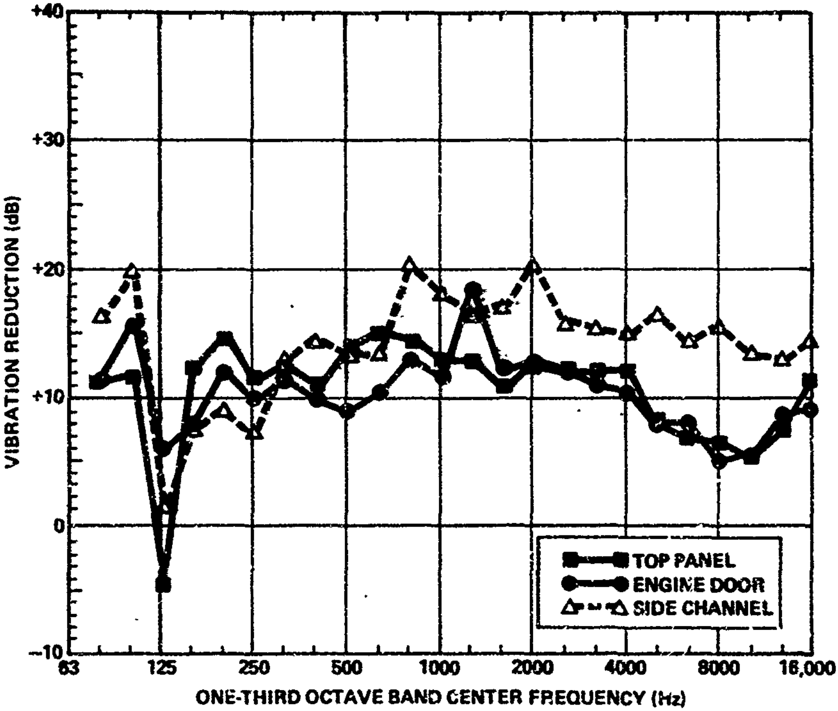



FIG. 40. REDUCTION IN HOUSING PANEL VIBRATION DUE TO THE INSTALLATION OF RESILIENT MOUNTS.

# 3. PERFORMANCE

## 3.1 Acoustic Performance

### 3.1.1 Test Site

The noise levels produced by the fully treated generator set and the partially treated generator set were measured in a large open grass covered field at Hanscom Airfield, Bedford, MA. The test site is shown in Fig. 41. The area was free of reflecting objects for well over 100 yards in any direction. For all the tests quoted here the generator set was mounted on the trailer shown in Fig. 5. Microphones were placed at a height of 1.5 m above the ground and at distances of 7.5 m and 20 m from the walls of the generator set housing. Measurements were made at four positions around the set at each of the two microphone distances as shown in Fig. 42. Although the noise from aircraft operations in the area did pose a problem on occasion, there were

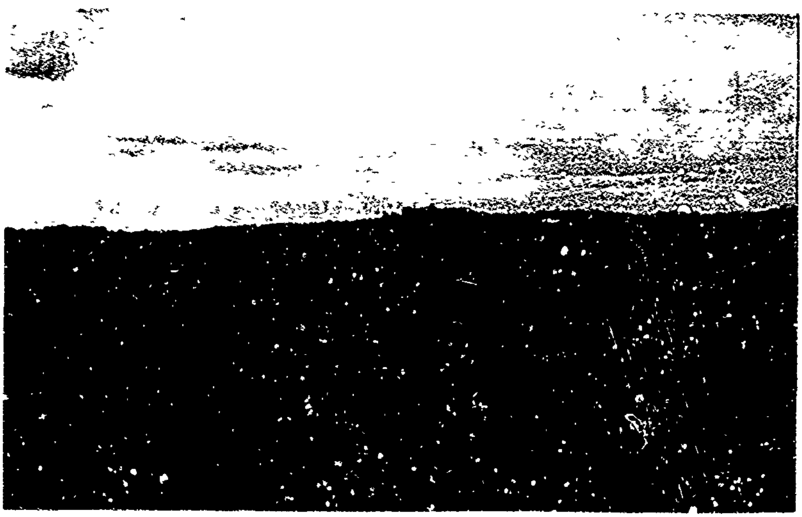


FIG. 41. THE ACOUSTIC TEST SITE.

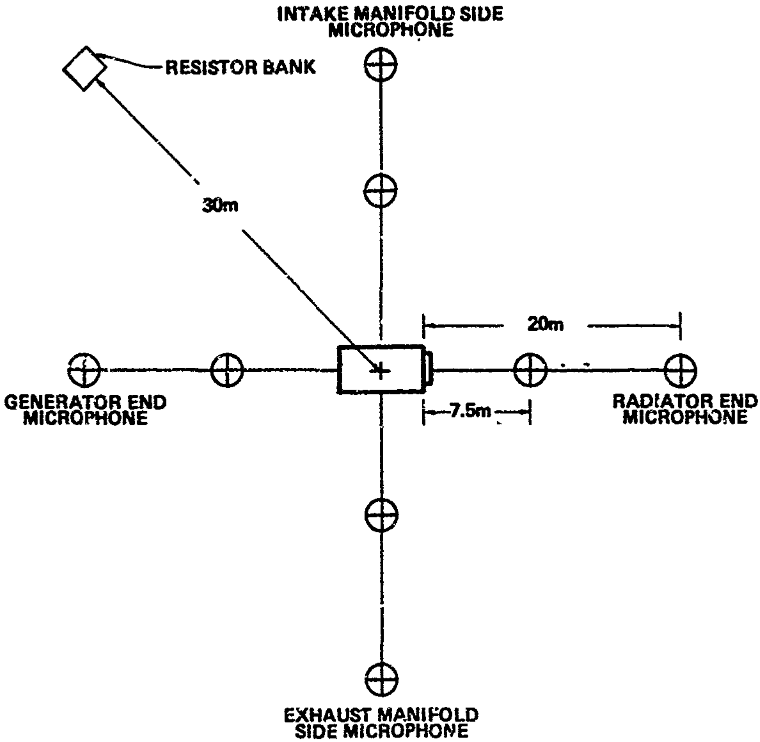



FIG. 42. MICROPHONE CONFIGURATION AT THE TEST SITE.

sufficient intervals during which the background noise did not interfere with the measurements.

### 3.1.2 Instrumentation

Standard acoustic instrumentation with calibration traceable to the National Bureau of Standards was used for all tests. The microphones were B&K model 4133 1/2 in. microphones with General

Radio Model P-42 microphone preamplifiers. All data were recorded on a two track Kudelski NAGRA IV-SJ, reel to reel tape recorder. All microphones were calibrated on site using a B&K model 4222 pistonphone calibrator. The tape recordings were later analyzed in the laboratory using a Nicolet 446 Mini-ubiquitous Spectrum Analyzer.

### 3.1.3 Results

A summary of the overall A-weighted sound levels and the estimated detection distances for the fully treated, partially treated and untreated generators are shown in Table 3. One third octave band spectra of the noise from these generators at the four, 20 meter microphone positions around the set are shown in Figs 43-46.

The fully treated set shows a reduction in noise at the 7.5 meter microphone position of between 16 and 17.5 dBA. The reduction at the 20 meter microphone position is similar and varies between 16.5 and 18 dBA. This represents a very substantial reduction in radiated noise. To the ear the set appears to be about one quarter as noisy as it was originally. Detection distances, estimated using the criteria of Ref. 1, have been reduced to 400 meters or less, i.e., more than 100 meters below the program goal. This represents a significant reduction in the radius around the set within which it can be heard. Recall that the original set could be heard out to a distance of 1100 meters.

The performance of the partially treated set is, as anticipated, somewhat less impressive. Noise reductions vary from as low as 3.5 dBA to as high as 9 dBA. The higher A-weighted sound level at the generator end is due primarily to the lack of any acoustic treatment in the auxiliary cooling air inlet. The measured noise levels when compared to the criteria of Ref. 1, result in detection distances from 600 to 750 meters depending on position. Noise levels in the 100 Hz third octave band are primarily responsible for pushing the detection distance to beyond

TABLE 3. RESULTS OF THE ACOUSTIC PERFORMANCE MEASUREMENTS FULLY TREATED GENERATOR SET.

| Measurement Position | A-Weighted Level [dBA] 7.5 meters | A-Weighted Level [dBA] 20 meters | Detection Distance [meters] |
|---|---|---|---|
| Radiator end | 67 | 60 | 350 |
| Intake side | 62.5 | 55 | 350 |
| Generator end | 67.5 | 59 | 400 |
| Exhaust side | 64.5 | 56 | 400 |

Partially Treated

| Measurement Position | A-Weighted Level [dBA] 7.5 meters | A-Weighted Level [dBA] 20 meters | Detection Distance [meters] |
|---|---|---|---|
| Radiator end | 75.5 | 67.5 | 600 |
| Intake side | 74.5 | 66.5 | 750 |
| Generator end | 79.5 | 72.0 | 650 |
| Exhaust side | 75.5 | 67.0 | 750 |

Untreated

| Measurement Position | A-Weighted Level [dBA] 7.5 meters | A-Weighted Level [dBA] 20 meters | Detection Distance [meters] |
|---|---|---|---|
| Radiator end | 84.5 | 76.5 | 1150 |
| Intake side | 80 | 72 | 950 |
| Generator end | 83.5 | 75.5 | 1150 |
| Exhaust side | 82 | 74 | 1100 |

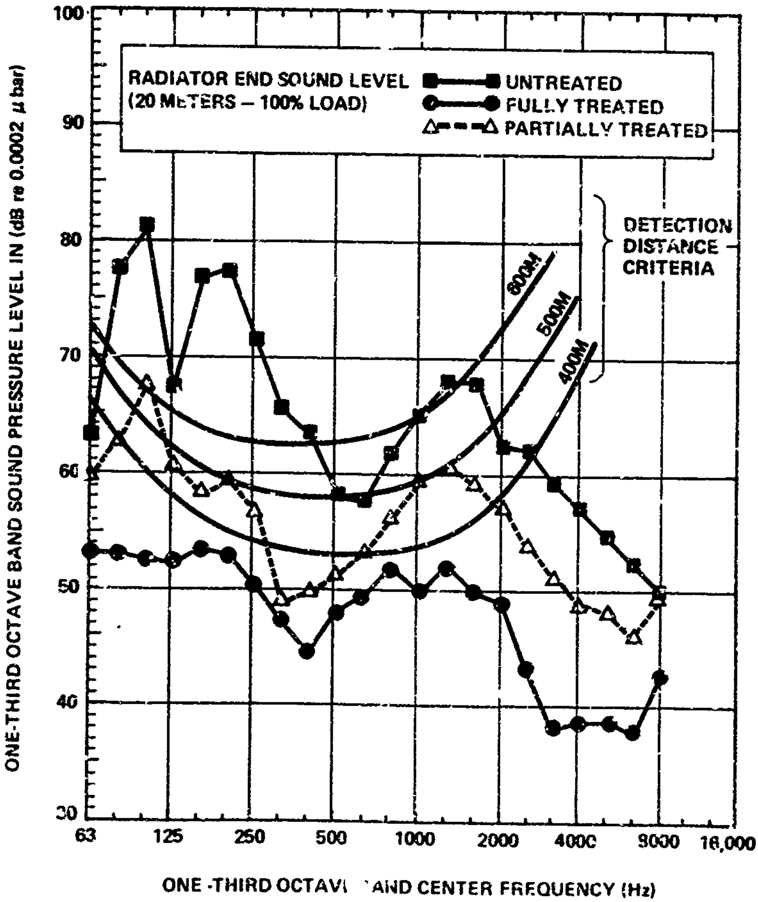



FIG. 43. ONE THIRD OCTAVE BAND SOUND PRESSURE LEVEL AT 20 METERS FROM THE GENERATOR SET HOUSING AT THE RADIATOR END WITH THE SET OPERATING AT FULL LOAD WHILE MOUNTED ON ITS TRAILER ON GRASSY GROUND.

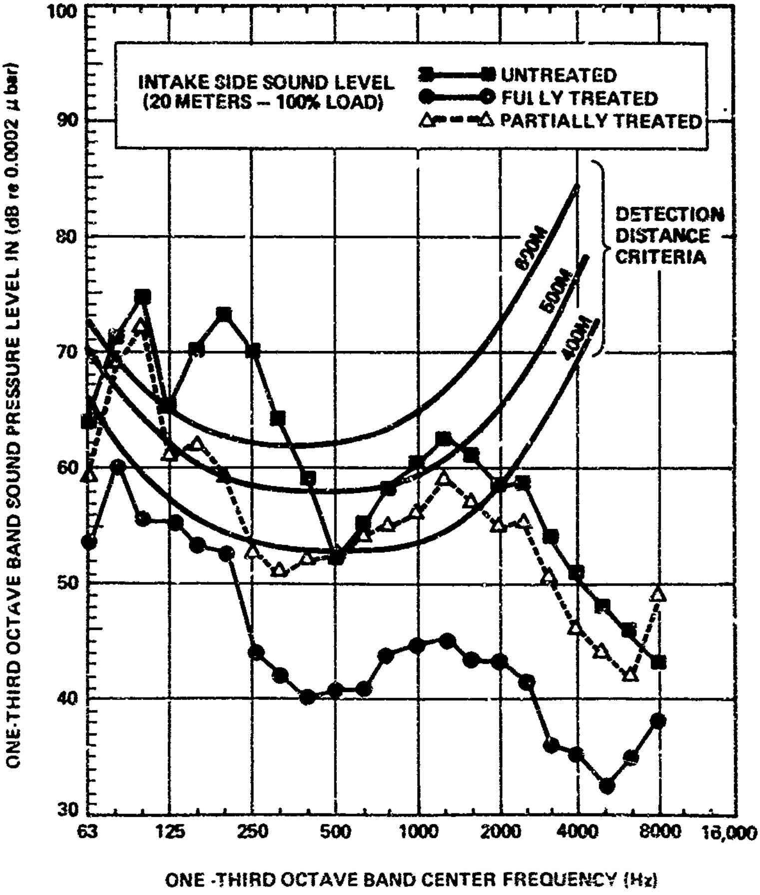



FIG. 44. ONE THIRD OCTAVE BAND SOUND PRESSURE LEVEL AT 20 METERS FROM THE GENERATOR SET HOUSING AT THE INTAKE SIDE WITH THE SET OPERATING AT FULL LOAD WHILE MOUNTED ON ITS TRAILER ON GRASSY GROUND.

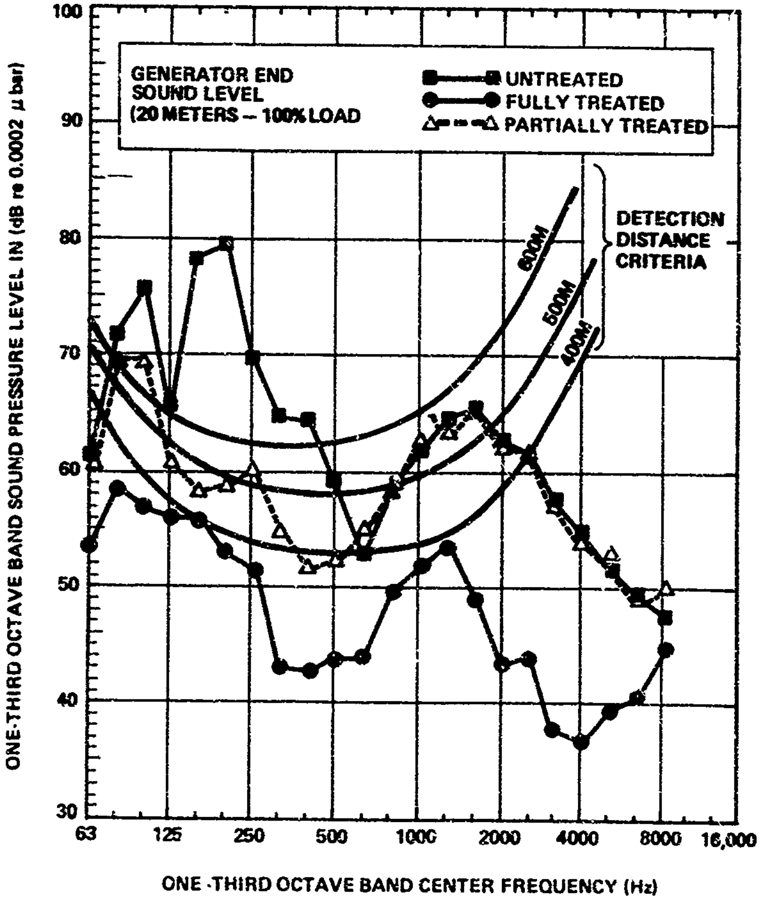



FIG. 45. ONE THIRD OCTAVE BAND SOUND PRESSURE LEVEL AT 20 METERS FROM THE GENERATOR SET HOUSING AT THE GENERATOR END WITH THE SET OPERATING AT FULL LOAD WHILE MOUNTED ON ITS TRAILER ON GRASSY GROUND.

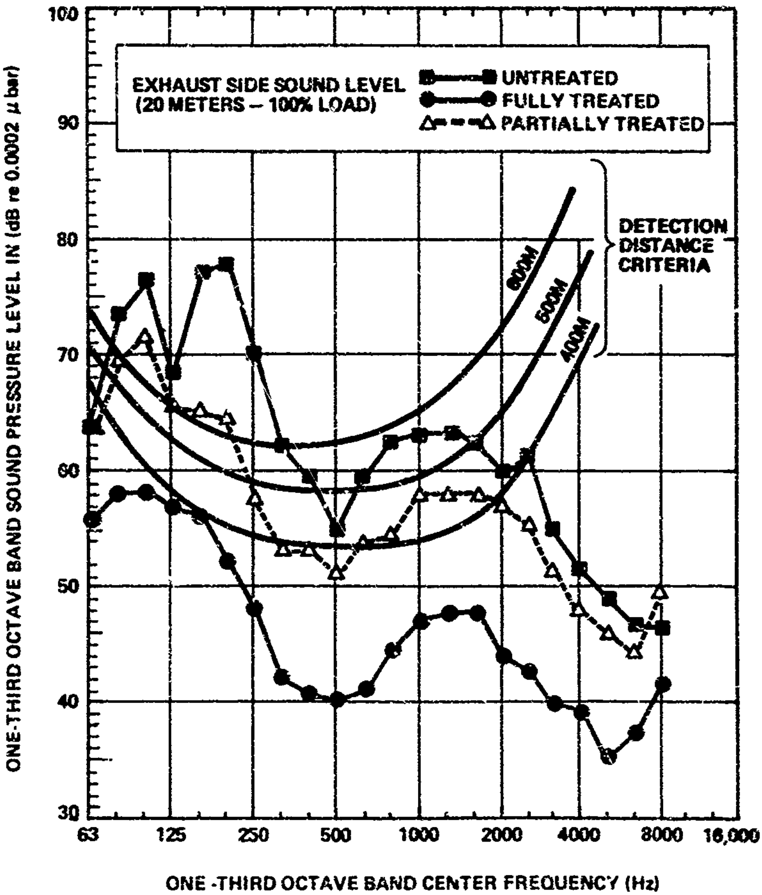



FIG. 46. ONE THIRD OCTAVE BAND SOUND PRESSURE LEVEL AT 20 METERS FROM THE GENERATOR SET HOUSING AT THE EXHAUST SIDE WITH THE SET OPERATING AT FULL LOAD WHILE MOUNTED ON ITS TRAILER ON GRASSY GROUND.

600 meters. Because of funding limitations no effort was made in this program to correct the problem in the 100 Hz third octave band. We anticipate that significant improvements could be made with minimal effort.

### 3.2 Cooling System Performance

The airflow through the fully treated set was measured using the same test apparatus described in Sec. 2.2.1. The fan speed was 1450 RPM, 73% of the original fan speed. With the generator setrun unloaded and the ambient temperature at 79°F, the air flow was 3765 CFM or 92% of the airflow untreated set. More importantly this air flow is 97% of the air flow measured in the pre-prototype that ran without difficulty at 124°F ambient temperature as described in Sec. 2.2.2. No air flow measurements were made on the partially treated generator since the absence of the parallel baffle silencers should if anything result in increased airflow over that achieved in the fully treated unit.

No cooling system performance measurements were made on the fully treated prototype generator or the partially treated prototype since it was felt that the air flow measurements described above and the pre-prototype cooling system performance measurements of Sec 2.2.2 were sufficient to qualify the performance of the cooling system.

### 3.3 Weight Increase

The total weight added to the set for the fully treated configuration was approximately 480 lbs. Approximately 60 lbs of material was removed from the set in the course of replacing existing components with redesigned units such as the exhaust muffler and the access doors at the generator end of the set. Consequently, the total weight increase in the fully treated set was approximately 420 lbs.

The total weight added to the partially treated set was 167 lbs with 23 lbs removed for a total weight increase of 144 lbs.

# 4. CONCLUSIONS AND RECOMMENDATIONS

## 4.1 Conclusions

The results of this study have conclusively demonstrated that the acoustic signature of the DOD 30 KW diesel engine-driven generator set can be significantly reduced with modest increases in weight and outside dimensions of the set. The current fully treated set is detectable only at distances less than 400 meters. In addition the A-weighted noise level in the vicinity of the set has been reduced by 16 to 18 dBA, resulting in nearly a factor of four reduction in perceived noisiness. These reductions in noise have been achieved with an increase in weight of only 420 lbs, and an increase in fixed outside dimensions of the set that consists of only a 12 in. increase in height. The cooling air inlet and discharge silencers do add approximately 12 in. to the front and rear of the set when installed. However, those components are designed to be easily removable by one person. As a result if those silencers should present a space problem during transport, for example, they can be removed and reinstalled when the set reaches its destination.

One of the most important lessons of the two phases of this program is that the methodical application of modern noise control technology can provide dramatic reductions in the acoustic signature of U. S. Army equipment. In addition these reductions can be achieved even in the presence of significant restrictions on the size and weight of the noise control package.

## 4.2 Recommendations

While the program described above has conclusively demonstrated the feasibility of significantly reducing the acoustic signature of the DOD 30 KW diesel engine-driven generator set, there are still a number of tasks remaining before the design will be ready for installation on a large number of fielded 30 KW generators. These tasks include:

- further noise control engineering of the partially treated set,
- measurement of the infra-red signature,
- detection qualification tests,
- production engineering and
- extension to the 15KW and 60 KW sets.

The partially treated set achieved the 600 meter detection distance goal at one of the four positions around the set. Based on the very successful results with the fully treated unit we believe that the noise signature of that partially treated set could be made to achieve the desire noise reduction goal with the addition of very little treatment. For those applications where less noise reduction is required, the partially treated set offers a number of advantages in simplicity, ease of modifications, cost and weight that should be exploited.

The infra-red signature of the treated set should be measured using modern thermal imaging equipment and compared with the signature obtained from an untreated 30 KW set. Any hot spots should be corrected with the appropriate application of thermal insulating material or the diversion of cooling air to cool the affected area. In general we anticipate that the thermal signature of the set will be less detectable than the signature from an untreated set because we believe that the external wall temperature of the housing of the treated set will be lower. The lower wall temperatures will be a consequence of two conditions. First, the air flow through the treated set is essentially the same as through an untreated set. Second, the treated set employs the extensive use of acoustic absorption on the walls of the housing. Acoustic absorption has thermal insulating properties and would be expected to provide additional resistance to the flow of heat through the walls. In any event

the thermal imaging test would be a useful qualification test before the treatment package is fielded.

The reduction in detection distance for the treated sets described here has been estimated using a detection criterion developed in Ref. 1. That criterion was verified using field measurements carried out by the Applied Physics Laboratory of Johns Hopkins University. Unfortunately the Johns Hopkins measurements assumed that the shape of the frequency spectrum did not change, and that as noise control treatments were applied that only the overall level would decline. In fact as shown in Sec. 3 there has been such a significant change in the shape of the frequency spectrum of the noise from the set that a new set of field qualification measurements to refine the detection distance estimates of the treated sets is recommended.

The treatment package as currently configured was designed to be fully functional and durable but has not been production engineered. It is very likely that a design review by a qualified generator production or assembly firm could result in a number of design changes that could result in significant savings in weight and cost. It is important that such a review be made and that the suggested changes be carefully examined to ensure that they will not have a significant adverse effect on the acoustic performance, maintenance procedures or durability.

The treatment package applied to the 30 KW diesel generator can be adopted to its two-sister sets the 15 KW and the 60 KW. Although diagnostic testing and air flow measurements would have to be made to provide information on adjustments to the elements of the treatment package, the extension of the package should be straightforward.

## REFERENCES

1. P.J. Remington and W.E. Biker "Reducing the Acoustic Detectability of the 30 KW Diesel Generator Set," Bolt Beranek and Newman Inc., Report No. 5197, April 1982.

# APPENDIX

# DRAWINGS AND MATERIALS LIST

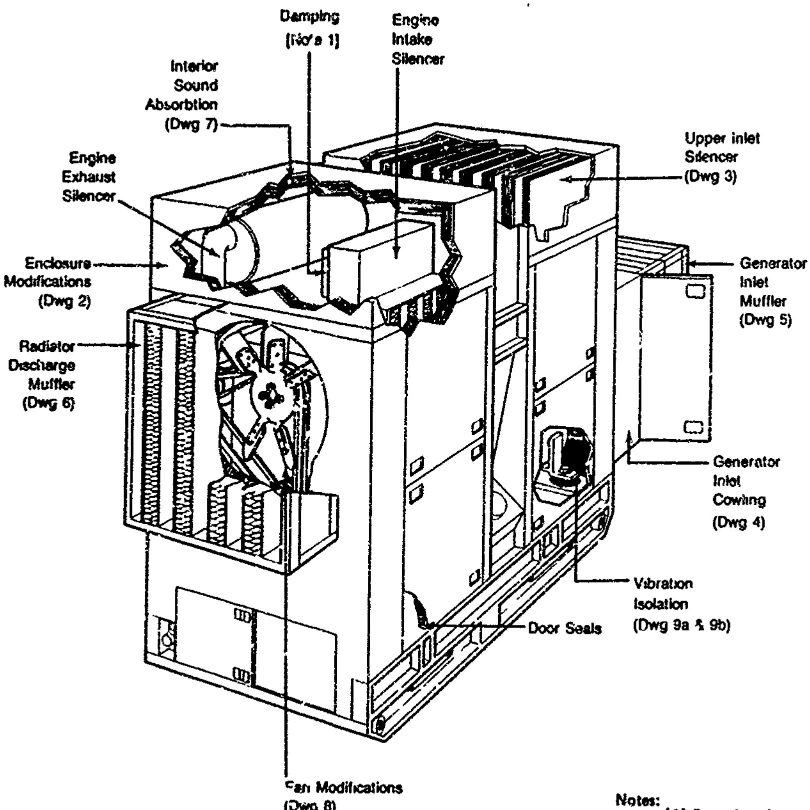
TABLE . MATERIALS LIST FOR 30 KW GENERATOR NOISE CONTROL TREATMENTS.

| Treatment | Drawing No. | Material | Size or Part No. | Estimated Quantity |
|---|---|---|---|---|
| Enclosure Modifications | 2 | Steel Sheet | 16 ga | 18 $ft^2$ |
| | | Steel Angle | 1 x 1 x 3/16 in | 14 ft |
| | | Steel Channel | C8 x 8.5 | 2 ft |
| | | Steel Plate | 1/4 in | 1.5 $ft^2$ |
| | | Wire Screen | 1/2 in sq | 4 $ft^2$ |
| | | Misc Hardware[1] | | |
| Upper Inlet Silencer | 3 | Steel Angle | 1 x 1 x 3/16 in | 4 ft |
| | | Steel Angle | 1/2 x 1/2 x 1/8 in | 10 ft |
| | | Aluminum Sheet[2] | 0.100 in | 24 $ft^2$ |
| | | Perf. Alum. Sheet[3] | 0.050 in | 34 $ft^2$ |
| | | Fiberglass Board[4] | 2 in. | 24 $ft^2$ |
| | | Nylon Netting[5] | XN-2330 | 30 $ft^2$ |
| | | Mylar Film[6] | 0.50 mil | 50 $ft^2$ |
| | | Wire Screen | 1/2 in sq | 3 $ft^2$ |
| | | Alum. Bar Stock | 1/4 in x 4 in | 3 ft |
| | | Drain Fittings | 1/2 in | 2 |
| | | Neop. Drain Hose | 1/2 in ID | 10 ft |
| | | Misc Hardware[1] | | |
| Generator Inlet Cowling | 4 | Steel Angle | 1 x 1 x 3/16 in | 12 ft |
| | | Steel Sheet | 16 ga | 16 $ft^2$ |
| | | Steel Bar Stock | 1/4 in x 3 in | 3 ft |
| | | Continuous Hinge | 1/8 in x 2 in | 6 ft |
| | | Paddle Latches | Mil. Spec | 2 |
| | | Wire Screen | 1/2 in sq | 10 $ft^2$ |
| | | Misc Hardware[1] | | |
| Generator Inlet Silencer | 5 | Aluminum Angle | 1 x 1 x 3/16 in | 50 ft |
| | | Aluminum Angle | 2 x 2 x 3/16 in | 4 ft |
| | | Aluminum Sheet[2] | 0.100 in | 15 $ft^2$ |
| | | Perf. Alum. Sheet[3] | 0.050 in | 64 $ft^2$ |
| | | Fiberglass Board[4] | 2 in | 24 $ft^2$ |
| | | Nylon Netting[5] | XN-2330 | 30 $ft^2$ |
| | | Mylar Film[6] | 0.50 mil | 80 $ft^2$ |
| | | Buna "D" Seal[7] | 2X8009 | 24 ft |
| | | Camloc Latches | 17L01-1X2AA | 4 |
| | | Camloc Strikes | 17L11-1-1AA | 4 |
| | | Misc Hardware[1] | | |
| Radiator Discharge Silencer | 6 | Steel Angle | 1 x 1 x 3/16 in | 8 ft |
| | | Aluminum Angle | 1 x 1 x 3/16 in | 16 ft |
| | | Aluminum Angle | 2 x 2 x 3/16 in | 4 ft |
| | | Aluminum Sheet[2] | 0.100 in | 8 $ft^2$ |
| | | Perf. Alum. Sheet[3] | 0.050 in | 26 $ft^2$ |
| | | Fiberglass Board[4] | 2 in | 12 $ft^2$ |

| Treatment | Drawing No. | Material | Size or Part No. | Estimated Quantity |
|---|---|---|---|---|
| Radiator Discharge Silencer (Cont'd.) | | Nylon Netting[5] | XN-2330 | 24 $ft^2$ |
| | | Mylar Film[6] | 0.50 mil | 30 $ft^2$ |
| | | Buna "D" Seal[7] | ZX8009 | 10 ft |
| | | Camloc Latches | 17L01-1X2AA | 2 |
| | | Camloc Strikes | 17L11-1-1XAA | 2 |
| | | Misc Hardware[1] | | |
| Interior Sound Absorption | 7 | Perf. Alum. Sheet[3] | 0.050 in | 64 $ft^2$ |
| | | Fiberglass Board[4] | 2 in | 64 $ft^2$ |
| | | Nylon Netting[5] | XN-2330 | 84 $ft^2$ |
| | | Mylar Film[6] | 0.50 mil | 110 $ft^2$ |
| | | Pop Rivets | | |
| Modified Fan Drive | 8 | Ball Bearing[8] | 602RS | 1 |
| | | Crank Shaft Pulley[9] | 2700-1 in | 1 |
| | | Idler/Tensioner[10] | | 1 |
| | | V-Belt | | 1 |
| | | Aluminum Stock | | |
| | | Misc Hardware[1] | | |
| Vibration Isolation | 9 | Vib. Iso. Mounts[11] | 508-3-N-S | 2 |
| | | Vib. Iso. Mounts[11] | 510-4-N-S | 2 |
| | | Misc Hardware[1] | | |
| Vibration Damping | - | Dyad 606 | 0.05 in | 8 $ft^2$ |
| | | Dyad Adhesive | - | 1 lb |
| Door Seals | - | Closed Cell Neoprene | 1/2 x 5/16 in | 60 ft |
| Engine Exhaust Silencer | - | Nelson Muffler | 20212N | 1 |
| | | Steel Strap | 1/4 in x 3 in | 8 in |
| | | Silicone Rubber Sheet | 1/4 in | 1/4 $ft^2$ |
| | | Aluminum Sheet | 1/4 in | 1/4 $ft^2$ |
| Engine Intake Silencer | - | Nelson Muffler | 91469A | 1 |

**Notes:**

[1]Misc hardware primarily 1/4, 3/8, 1/2 in bolts, nuts, washers, pop rivets, etc.
[2]5052-H32
[3]1/8 in dia. holes on 3/16 in staggered centers.
[4]Owens Corning Type 703.
[5]Internet Corp.
[6]Dupont.
[7]Minor Rubber Co.
[8]Atlantic Tracy - 122 KSFF MRC Bearing.
[9]Atlantic Tracy - Maurey Pulley.
[10]Atlantic Tracy - Fafnir Pulley 010-1037/Brewer Tensioner 1S166.
[11]Barry Controls, Inc.




Notes:
[1] Damping also applied to right side of oil pan.

| Bolt Beranek and Newman Inc. Cambridge Massachusetts | | | |
|---|---|---|---|
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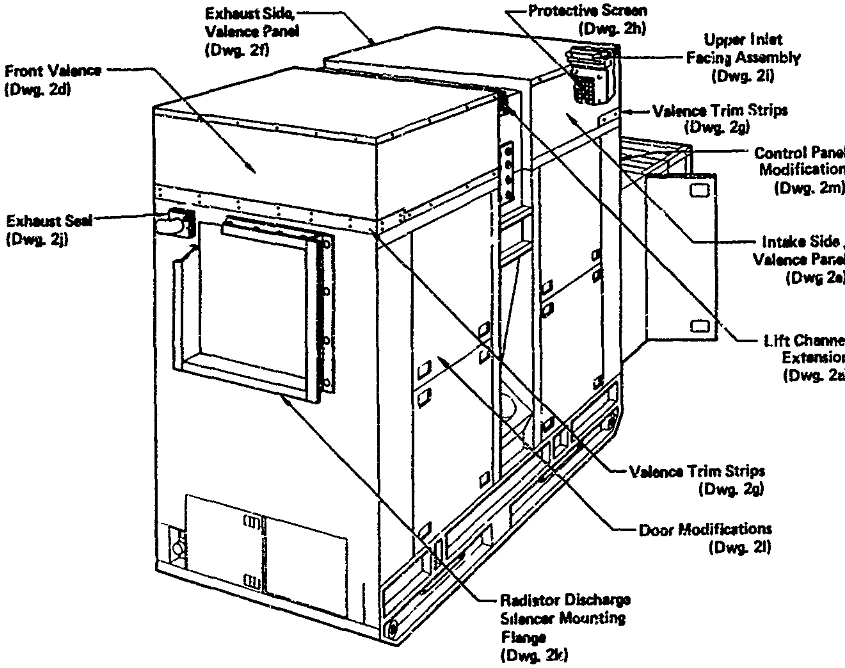


| Bolt Beranek and Newman Inc. Cambridge Massachusetts | | | |
|---|---|---|---|
| DRAWING TITLE: ENCLOSURE MODIFICATIONS | | | |
| SIZE A | CODE IDENT NO. | DRAWING NO. 2 | |
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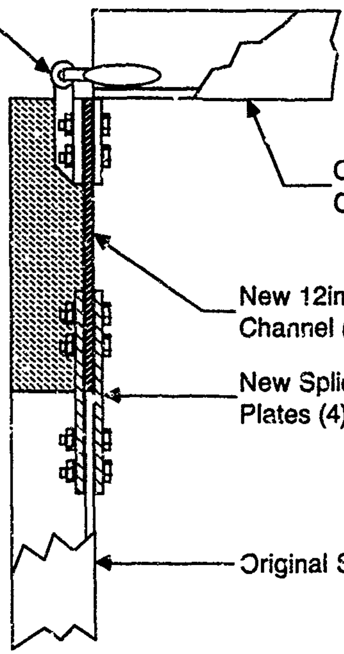


Bolt Beranek and Newman Inc.
Cambridge Massachusetts

| DRAWING TITLE | | |
|---|---|---|
| LIFT CHANNEL EXTENSION ASSEMBLY | | |
| SIZE A | CODE IDENT NO. | DRAWING NO. 2A |
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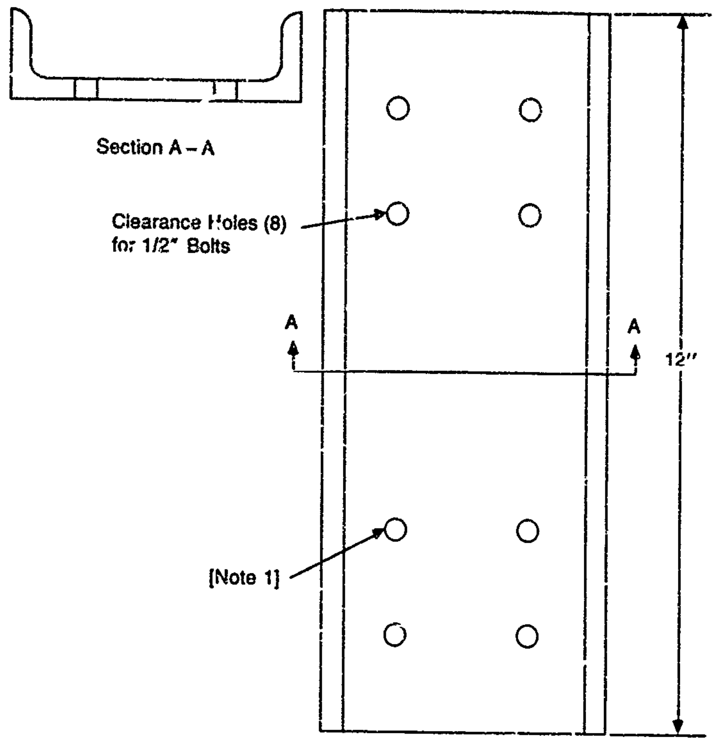


Note:

[1] Match existing bolt Pattern

Material: C8 x 8.5 in. Steel Channel

Quantity: 2

**Bolt Beranek and Newman Inc.**
Cambridge Massachusetts

| DRAWING TITLE | | |
|---|---|---|
| LIFT CHANNEL EXTENSION | | |
| SIZE A | CODE IDENT NO. | DRAWING NO. 2B |
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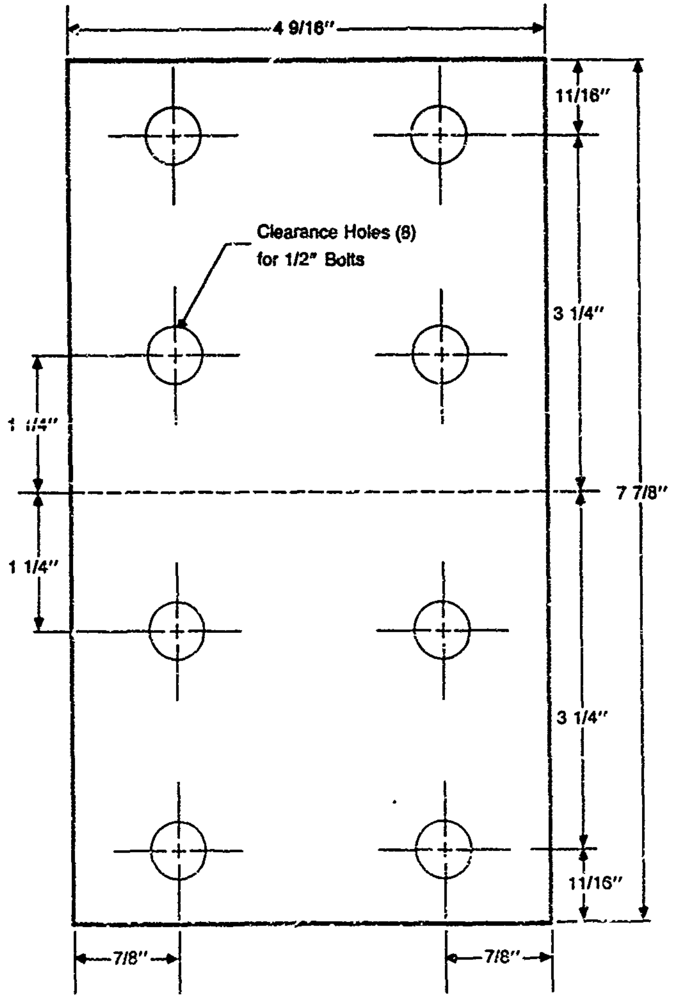
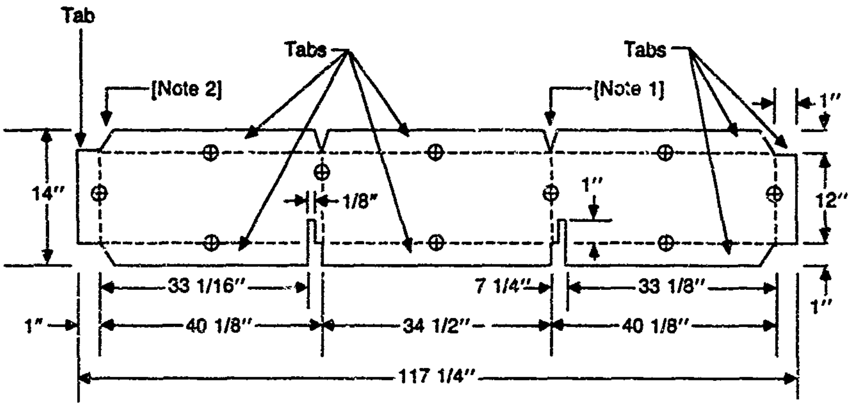


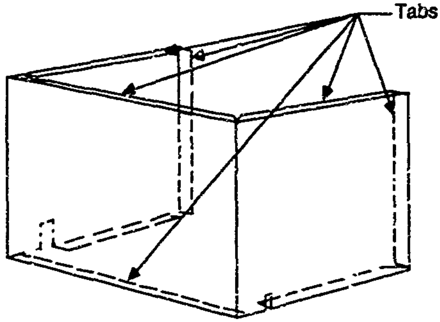

Material: 1/4 in. steel
Quantity: 4

| | | |
|---|---|---|
| Bolt Beranek and Newman Inc. Cambridge Massachusetts | | |
| DRAWING TITLE<br>LIFT CHANNEL EXTENSION SPLICE PLATES | | |
| SIZE A | CODE IDENT NO | DRAWING NO. 2C |
| SCALE None | WGT. EST CALC | SHEET 5 OF 73 |




Plan View

⊕ Bend – down 90°
⊙ Bend – up 90




Folded View

Notes:

[1] Cut at 45°, 2 places
[2] Cut at 22.5°, 4 places

Material: 16 ga steel
Quantity: 1

Bolt Beranek and Newman Inc.
Cambridge Massachusetts

| DRAWING TITLE | | |
|---|---|---|
| FRONT VALANCE PANEL | | |
| SIZE A | CODE IDENT NO. | DRAWING NO. 2D |
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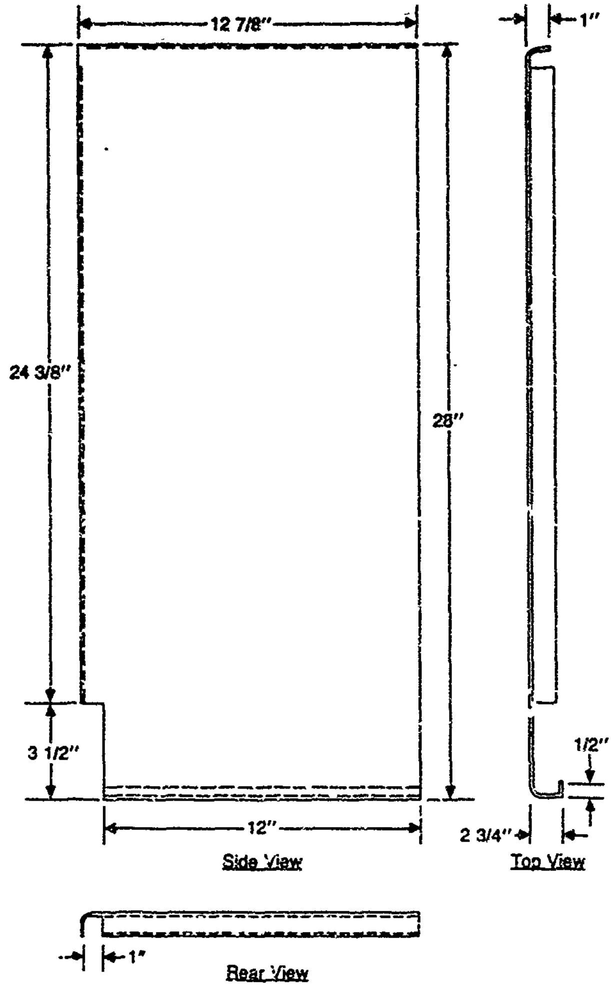



Material: 16 ga steel
Quantity: 1

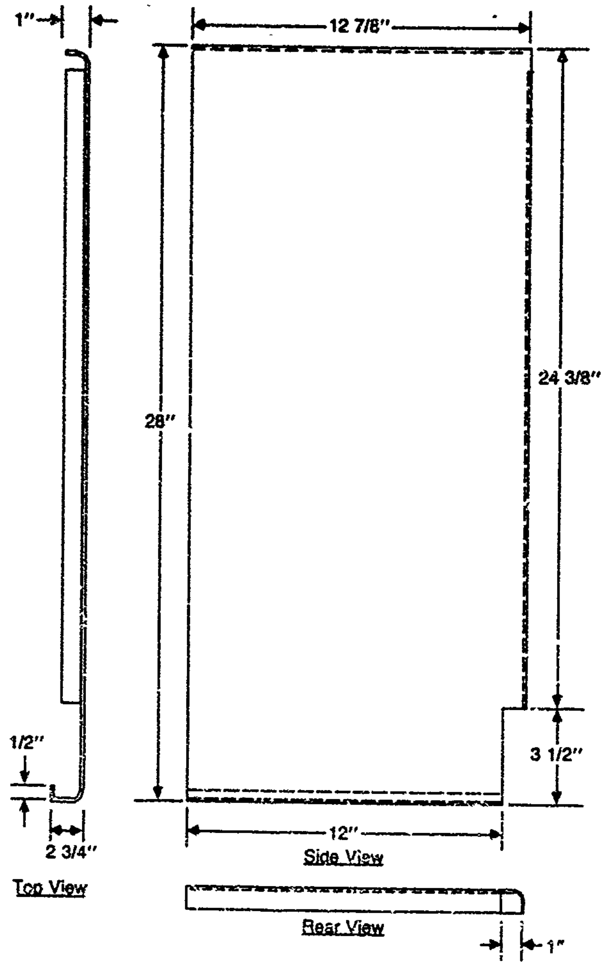
**Bolt Beranek and Newman Inc.**
Cambridge Massachusetts

DRAWING TITLE

INTAKE SIDE VALANCE PANEL

| SIZE | CODE IDENT NO. | DRAWING NO. |
|---|---|---|
| A | | 2E |

| SCALE | WGT: EST CALC | SHEET |
|---|---|---|
| None | | 7 OF 72 |




Material: 16 ga steel
Quantity: 1

Bolt Beranek and Newman Inc.
Cambridge Massachusetts

DRAWING TITLE

EXHAUST SIDE VALANCE PANEL

| SIZE | CODE IDENT NO. | DRAWING NO. |
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|---|---|---|
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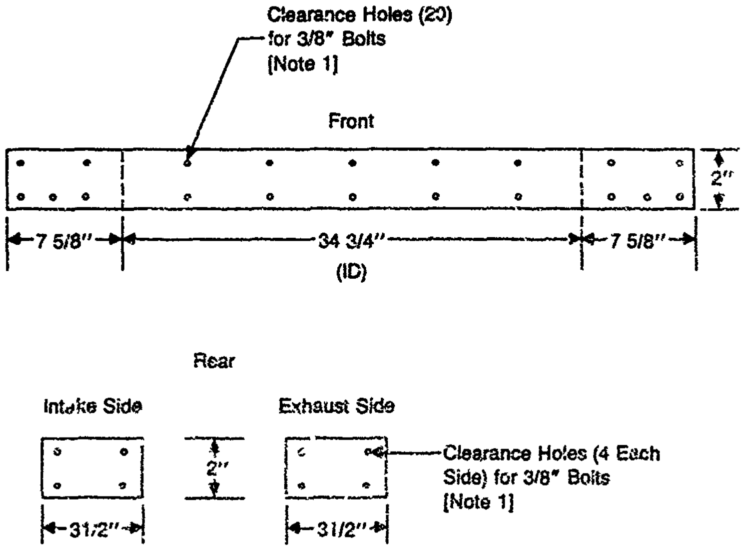


Note: [1] Drill Bolt Holes to Match Existing Pattern

Material: 16 ga steel
Quantity: 1 ea

Bolt Beranek and Newman Inc.
Cambridge Massachusetts

DRAWING TITLE
VALANCE TRIM STRIPS

| SIZE | CODE IDENT NO. | DRAWING NO. |
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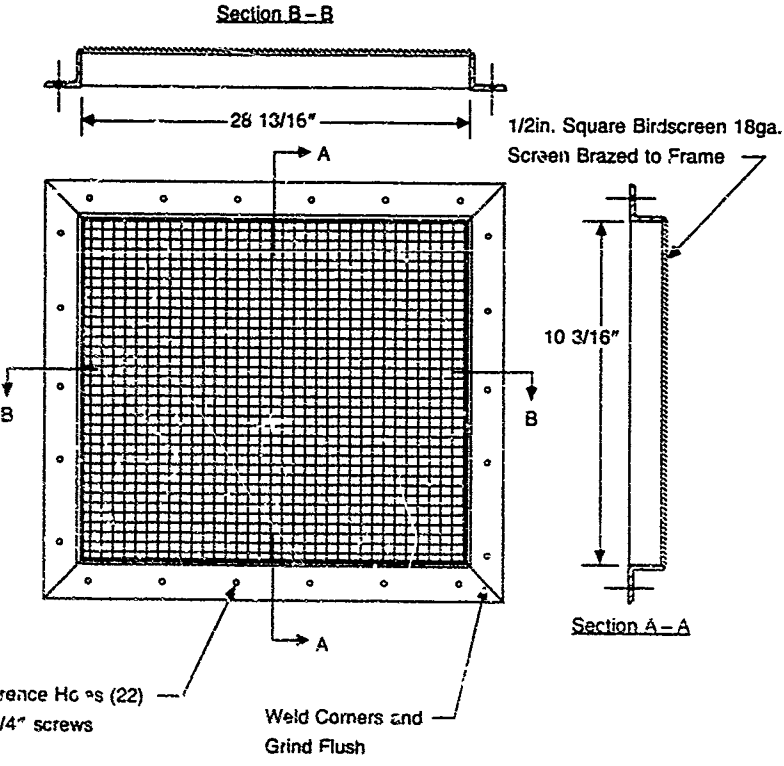
| A | | 2G |

| SCALE None | WGT: EST CALC | SHEET 9 OF 73 |
|---|---|---|




**Bolt Baranek and Newman Inc.**
Cambridge Massachusetts

DRAWING TITLE

UPPER INTAKE PROTECTIVE SCREEN

| SIZE | CODE IDENT NO | DRAWING NO. |
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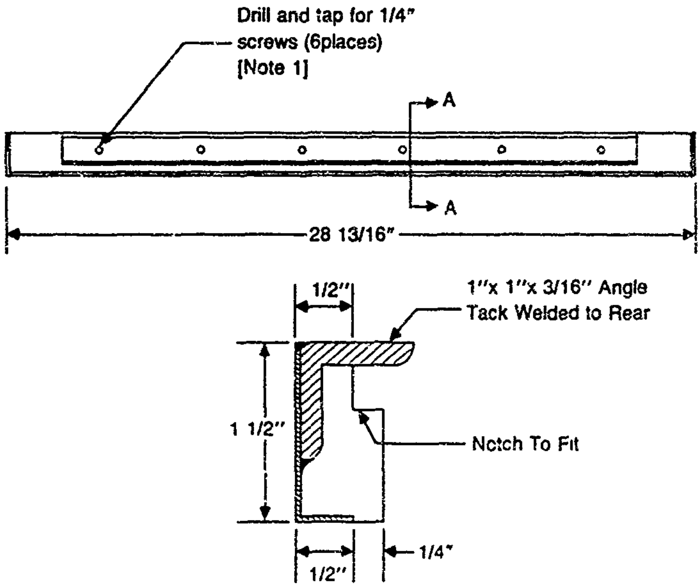
| A | | 2H |

| SCALE | WGT- EST CALC | SHEET |
|---|---|---|
| None | | 10 of 73 |




Section A – A

Notes:

[1] Hole pattorn to match that on protective screen flange

Material: 16 ga steel
1 x 1 x 3/6 steel angle

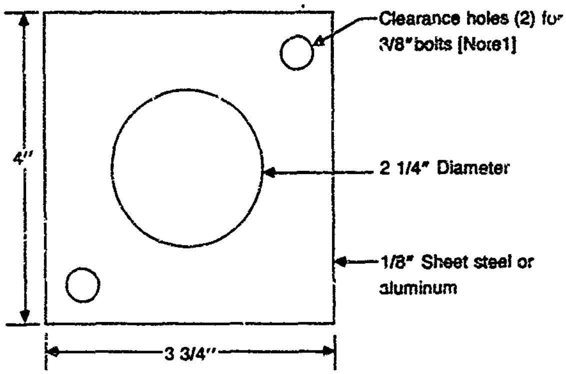
Quantity: 1

Bolt Beranek and Newman Inc.
Cambndge Massachusetts

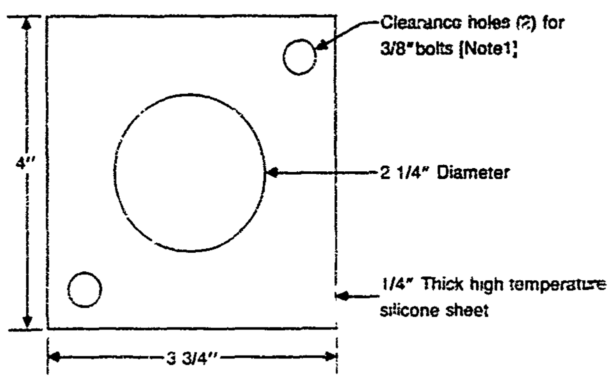
DRAWING TITLE
UPPER INTAKE FACING ASSEMBLY

| SIZE | CODE IDENT NO | DRAWING NO |
|---|---|---|
| A | | 21 |

SCALE None | WGT EST CALC | SHEET 11 OF




Seal Retainer




Exhaust Pipe Seal

Notes.

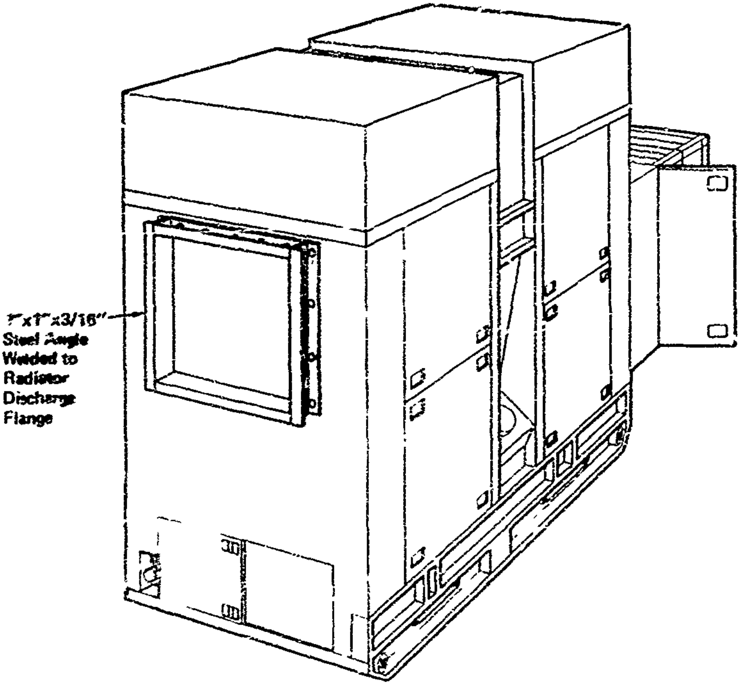
[1] Hole location to match existing rain cap mounting holes.

Material: 1/4 in. silicone
Quantity: 1 ea

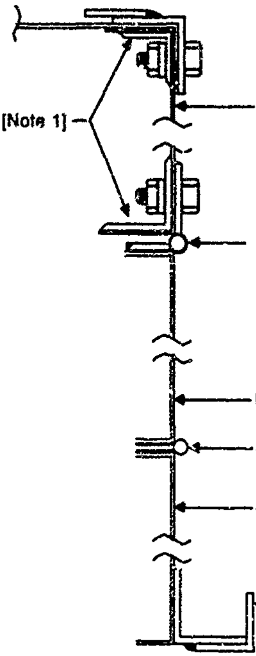
| | |
|---|---|
| BBN | Bolt Beranek and Newman Inc. Cambridge Massachusetts |
| DRAWING TITLE | EXHAUST PIPE SEAL AND RETAINER |

| SIZE | CODE IDENT NO | DRAWING NO |
|---|---|---|
| A | | 23 |

| SCALE | WGT EST CALC | SHEET |
|---|---|---|
| None | | 12 OF 7[illegible] |



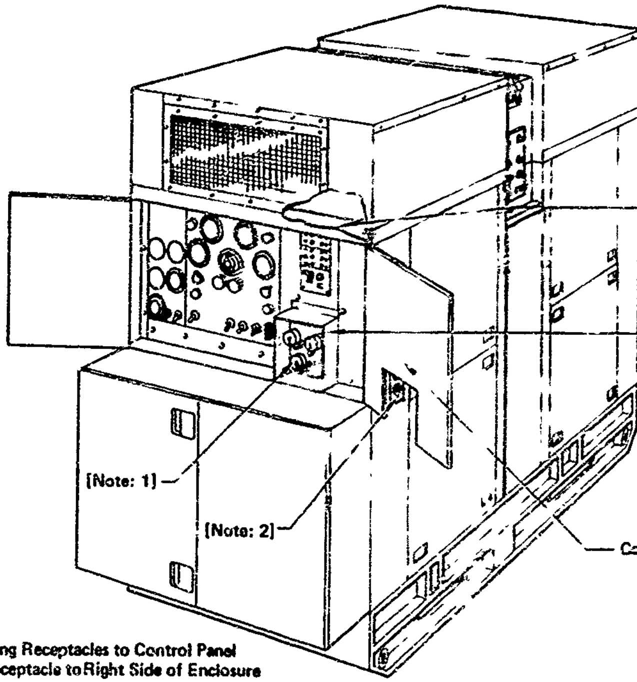

| | | |
|---|---|---|
| Bolt Beranek and Newman Inc. Cambridge Massachusetts | | |
| DRAWING TITLE: RADIATOR DISCHARGE SILENCER MOUNTING FLANGE | | |
| SIZE: A | CODE IDENT NO | DRAWING NO. 2K |
| SCALE: None | WGT | SHEET 13 OF 73 |




Notes:

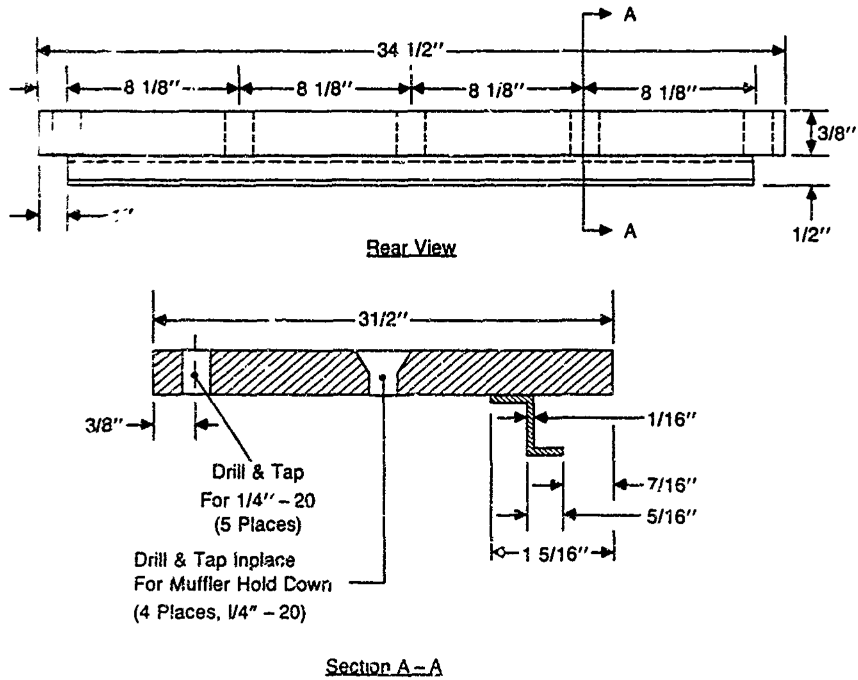
[1] 1"x 1"x 3/16" Steel angle installed at top and bottom of valence panel drill & tap for 3/8" bolts to match existing hole patterns for roof panels and door hinges.

| | |
|---|---|
| BBN | Bolt Beranek and Newman Inc. Cambridge Massachusetts |
| DRAWING TITLE | DOOR MODIFICATIONS |
| SIZE: A | CODE IDENT NO.: |
| DRAWING NO. | 2L |
| SCALE | None |
| WGT. EST CALC | |
| SHEET 14 | OF 73 |




Notes:
(1) Relocate Paralleling Receptacles to Control Panel
(2) Relocate 110v Receptacle to Right Side of Enclosure

| | |
|---|---|
| Bolt Beranek and Newman Inc. Cambridge Massachusetts | |
| DRAWING TITLE: CONTROL PANEL MODIFICATIONS | |
| SIZE A | CODE IDENT NO | DRAWING NO 2M |
| SCALE None | WGT EST CALC | SHEET 15 OF 73 |

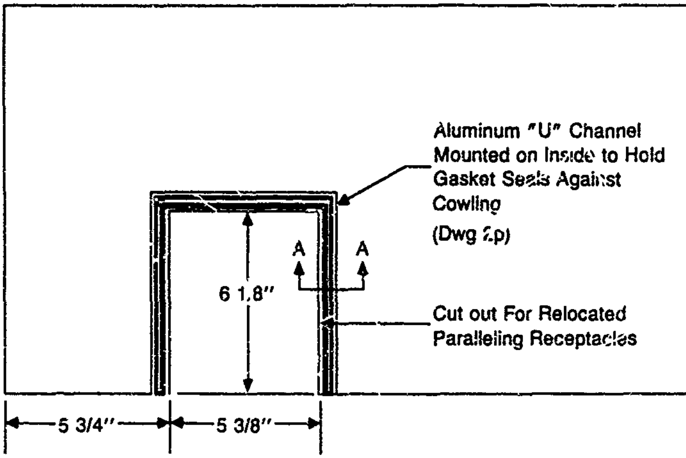


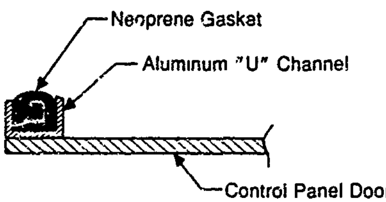

Bolt Beranek and Newman Inc.
Cambridge Massachusetts

DRAWING TITLE

AUXILIARY INTAKE SILENCER SILLPLATE

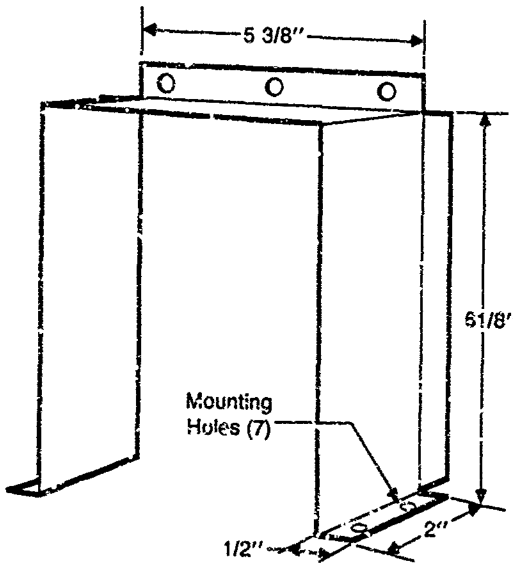
| SIZE | CODE IDENT NO. | DRAWING NO. | |
|---|---|---|---|
| A | | 2N | |
| SCALE None | WGT. EST CALC | SHEET 16 OF 73 | |



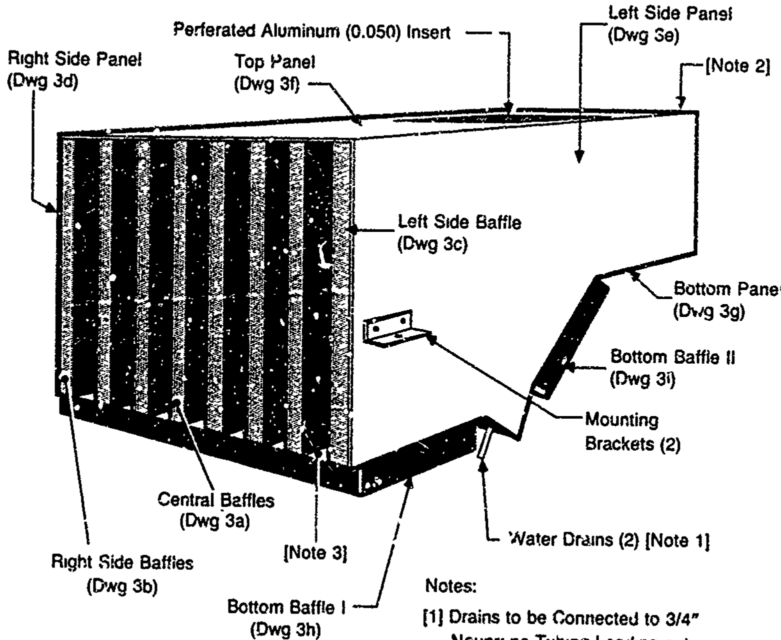

Section A – A

| | | | |
|---|---|---|---|
| Bolt Beranek and Newman Inc. Cambridge Massachusetts | | | |
| DRAWING TITLE: CONTROL PANEL DOOR MODIFICATIONS | | | |
| SIZE A | CODE IDENT NO | DRAWING NO. 20 | |
| SCALE None | WGT: EST CALC | SHEET 17 | OF 73 |




Material: 0.100 in. aluminum
Quantity: 1

| | |
|---|---|
| Bolt, Beranek and Newman Inc. Cambridge Massachusetts | |
| DRAWING TITLE: CONTROL PANEL COWLING | |
| SIZE A | CODE IDENT NO. |
| DRAWING NO. 2P | |
| SCALE None | WGT. EST. CALC |
| SHEET 18 OF 73 | |



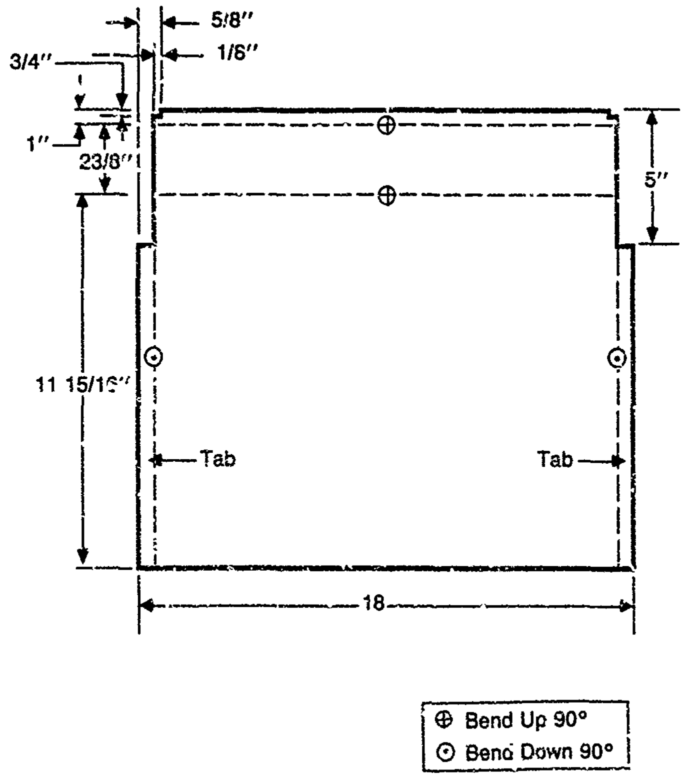

Notes:

[1] Drains to be Connected to 3/4" Neuprene Tubing Leading out of Enclousure

[2] Panel Corners to be Welded

[3] All Baffles Riveted to Panels Through Tabs

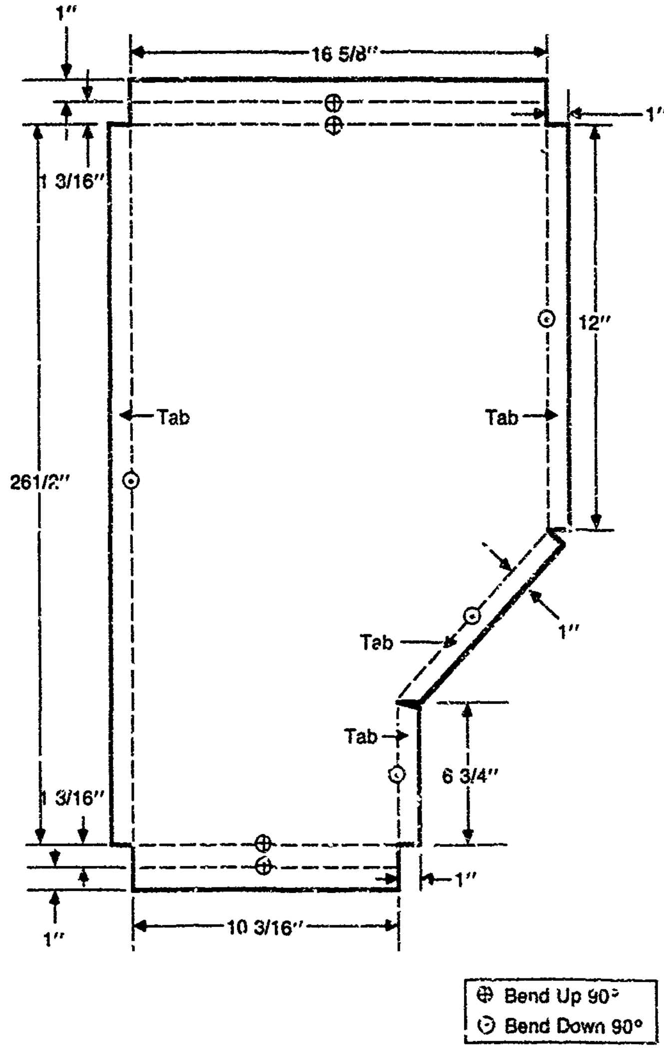
| | | | |
|---|---|---|---|
| BBN | Bolt Beranek and Newman Inc. Cambridge Massachusetts | | |
| DRAWING TITLE | UPPER INLET SILENCER ASSEMBLY | | |
| SIZE A | CODE IDENT NO. | DRAWING NO. 3 | |
| SCALE None | WGT: EST CALC | SHEET 19 OF 73 | |




Material: 0.50 in. Perforated Aluminum
Quantity: 12

Bolt Beranek and Newman Inc.
Cambridge Massachusetts

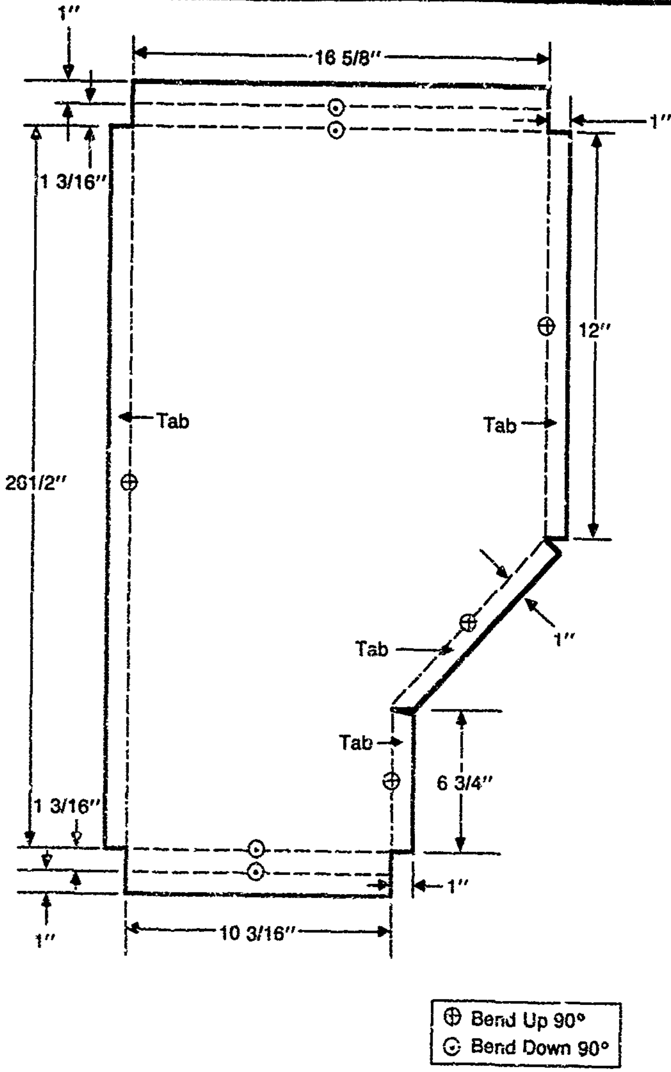
| | | |
|---|---|---|
| DRAWING TITLE | | |
| UPPER INLET SILENCER CENTRAL BAFFLES | | |
| SIZE A | CODE IDENT NO. | DRAWING NO. 3A |
| SCALE None | WGT. EST CALC | SHEET 20 OF 73 |




Material: 0.050 in. Perforated
          Aluminum
Quantity: 1

**Bolt Beranek and Newman Inc.**
Cambridge Massachusetts

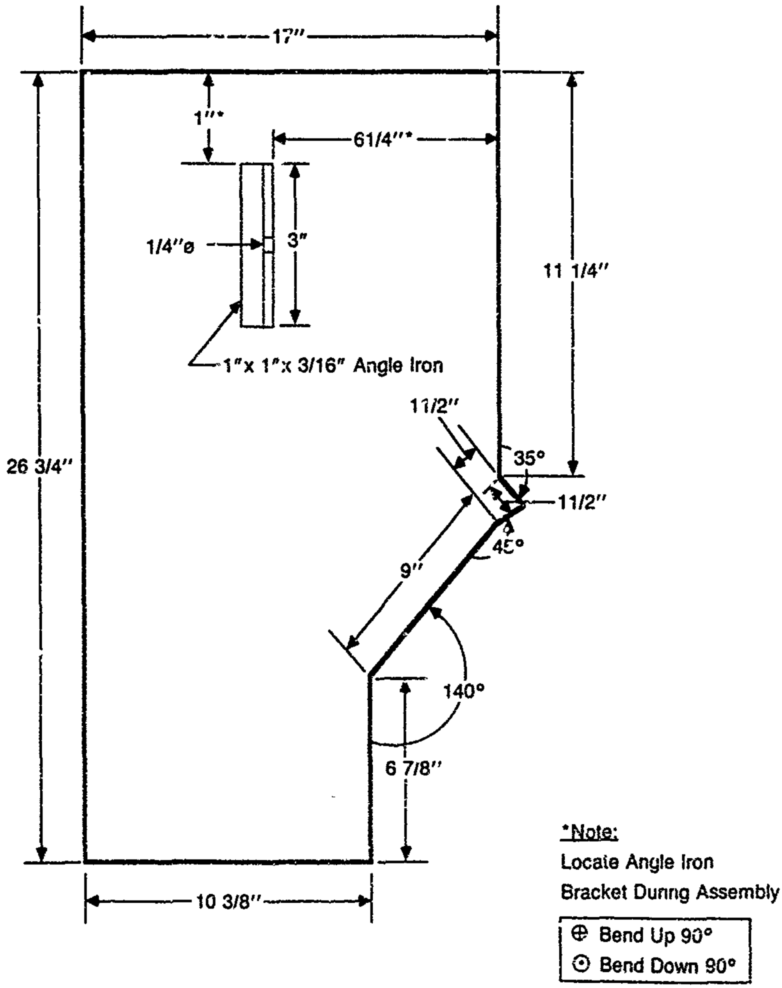
| DRAWING TITLE | | |
|---|---|---|
| UPPER INLET SILENCER LEFT SIDE BAFFLE | | |
| SIZE A | CODE IDENT NO. | DRAWING NO 3B |
| SCALE None | WGT. EST CALC | SHEET 21 OF 73 |




Material: 0.050 in. Perforated
Aluminum
Quantity: 1

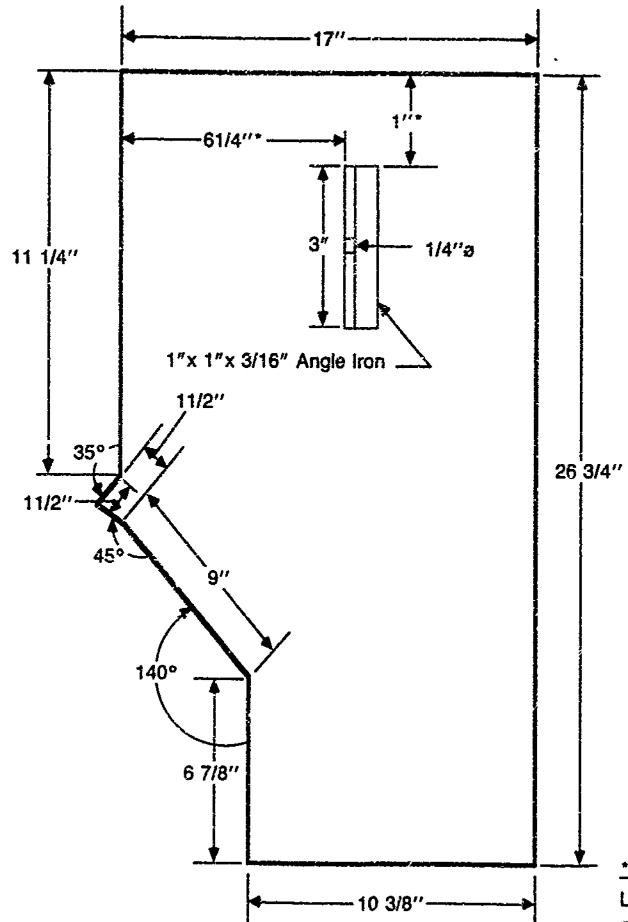
**Bolt Beranek and Newman Inc.**
Cambridge Massachusetts

| DRAWING TITLE | | |
|---|---|---|
| UPPER INLET SILENCER RIGHT SIDE BAFFLE | | |
| SIZE A | CODE IDENT NO. | DRAWING NO. 3C |
| SCALE None | WGT: EST CALC | SHEET 22 OF 73 |




Material: 0.100 in. Aluminum
Quantity: 1

| | | | |
|---|---|---|---|
| Bolt Beranek and Newman Inc. Cambridge Massachusetts | | | |
| DRAWING TITLE: UPPER INLET SILENCER LEFT SIDE PANEL | | | |
| SIZE: A | CODE IDENT NO. | DRAWING NO.: 3D | |
| SCALE: None | WGT: EST CALC | SHEET 23 OF 73 | |

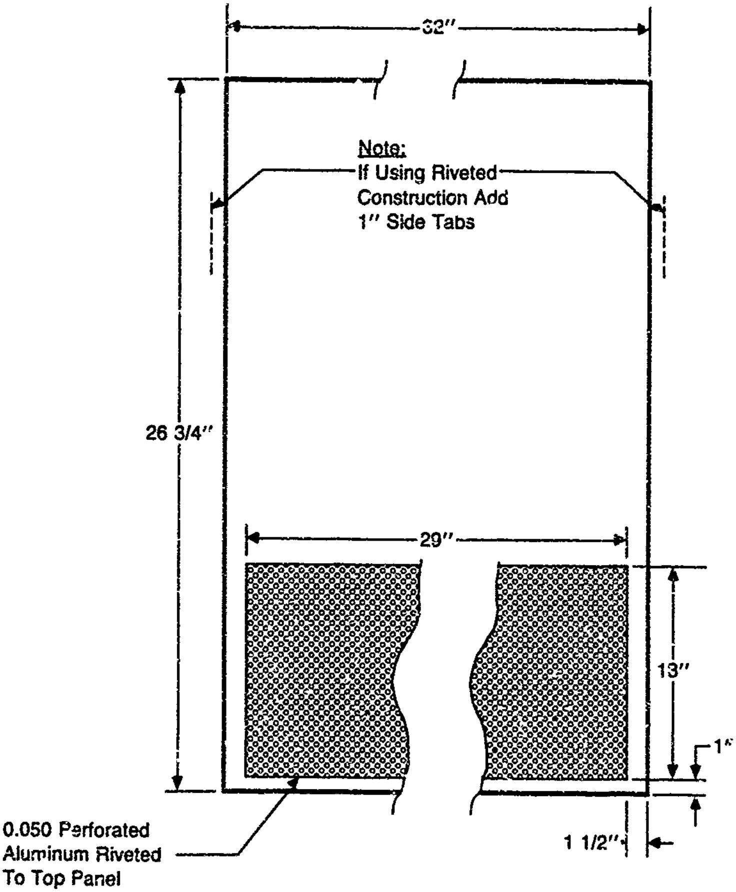



*Note:
Locate Angle Iron Bracket During Assembly

⊕ Bend Up 90°
⊙ Bend Down 90°

Material: 0.100 in. Aluminum
Quantity: 1

| Bolt Beranek and Newman Inc. Cambridge Massachusetts | | |
|---|---|---|
| DRAWING TITLE: UPPER INLET SILENCER RIGHT SIDE PANEL | | |
| SIZE: A | CODE IDENT NO. | DRAWING NO. 3E |
| SCALE: None | WGT: EST CALC | SHEET 24 OF 73 |



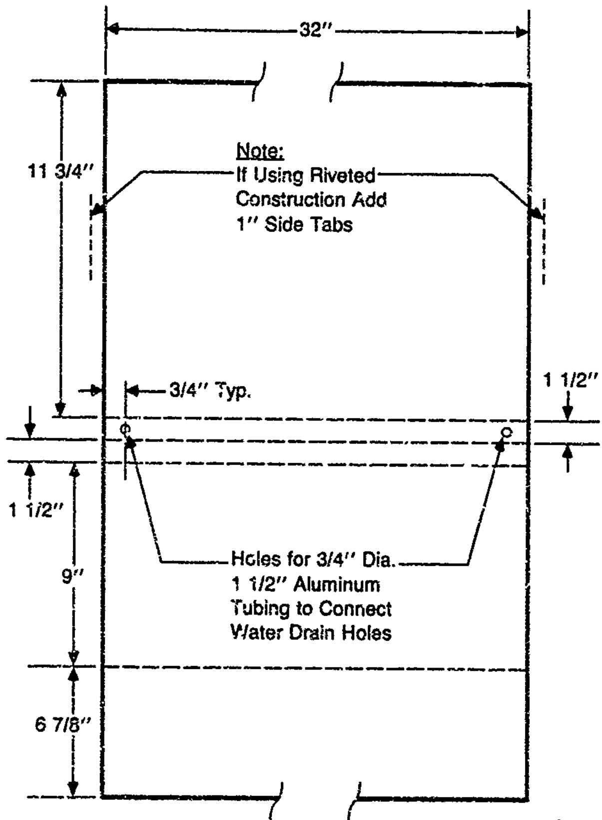

Material: 0.100 in. Aluminum
Quantity: 1

Bolt Beranek and Newman Inc.
Cambridge Massachusetts

DRAWING TITLE
UPPER INLET SILENCER TOP PANEL

| SIZE | CODE IDENT NO. | DRAWING NO. |
| --- | --- | --- |
| A | | 3F |

| SCALE | WGT: EST CALC | SHEET 25 OF 73 |
| --- | --- | --- |
| None | | |

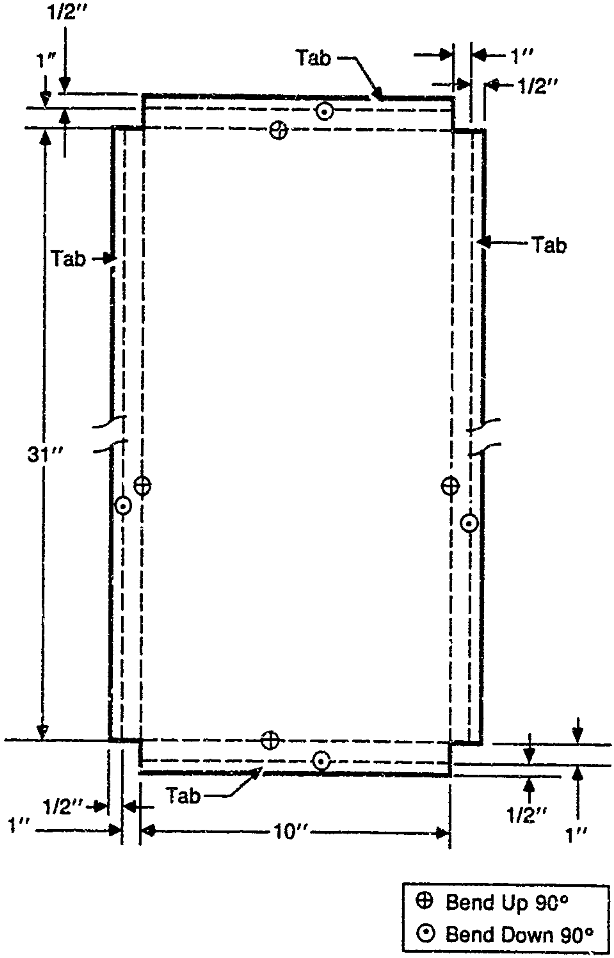



Note:
Bend Along Perforated Lines to Fit Side Panel

Material: 0.100 Aluminum
Quantity: 1

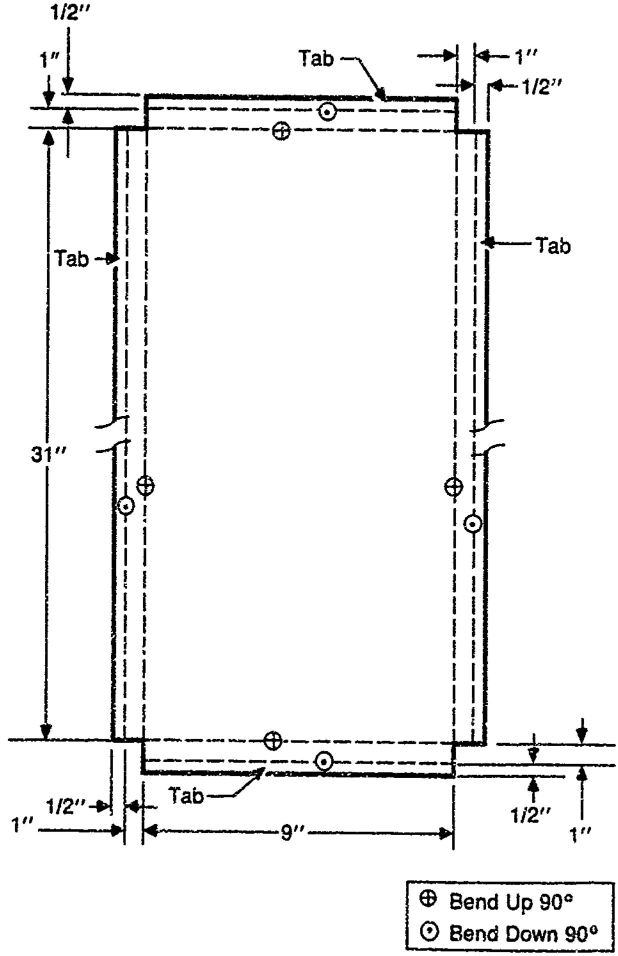
Bolt Beranek and Newman Inc.
Cambridge Massachusetts

| DRAWING TITLE | | |
|---|---|---|
| UPPER INLET SILENCER BOTTOM PANEL | | |
| SIZE A | CODE IDENT NO. | DRAWING NO. 3G |
| SCALE None | WGT: EST CALC | SHEET 26 OF 73 |




Material: 0.050 in. Perforated
Aluminum
Quantity: 1

| | | | |
|---|---|---|---|
| Bolt Beranek and Newman Inc. Cambndge Massachusetts | | | |
| DRAWING TITLE: UFPER INLET SILENCEP BOTTOM BAFFLE I | | | |
| SIZE: A | CODE IDENT NO. | DRAWING NO. 3H | |
| SCALE None | WGT. EST CALC | SHEET 27 OF 73 | |



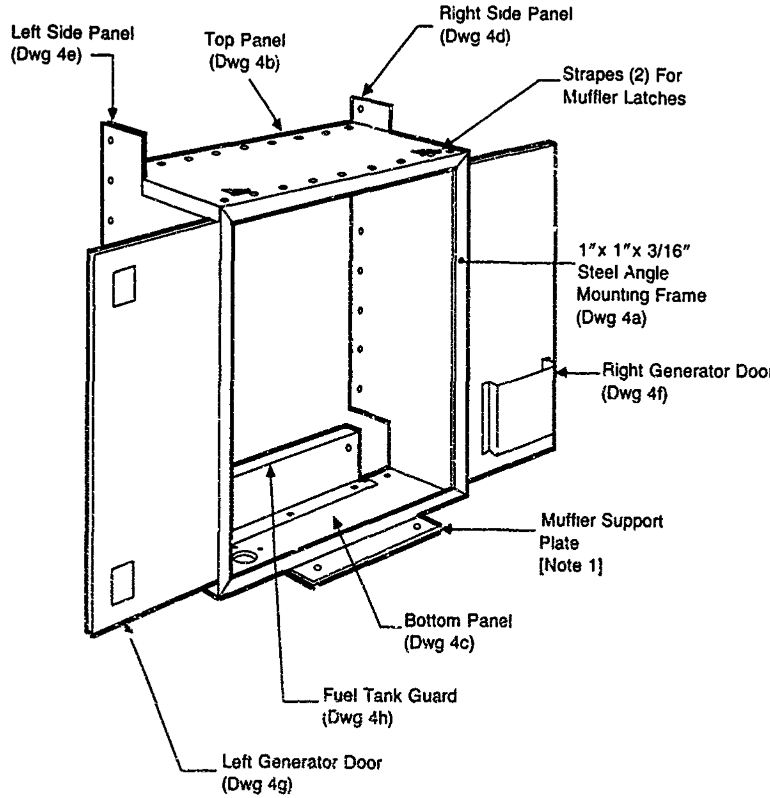

Material: 0.050 in. Perforated Aluminum
Quantity: 1

| | |
|---|---|
| Bolt Beranek and Newman Inc. | Cambridge Massachusetts |

DRAWING TITLE
UPPER INLET SILENCER BOTTOM BAFFLE II

| SIZE | CODE IDENT NO. | DRAWING NO. |
|---|---|---|
| A | | 31 |

| SCALE | WGT: EST CALC | SHEET |
|---|---|---|
| None | | 28 OF 73 |




Notes:

[1] 4"x 20 x 1/4" Steel muffler support plate bolted to frame – mounting holes to match pins on silencers

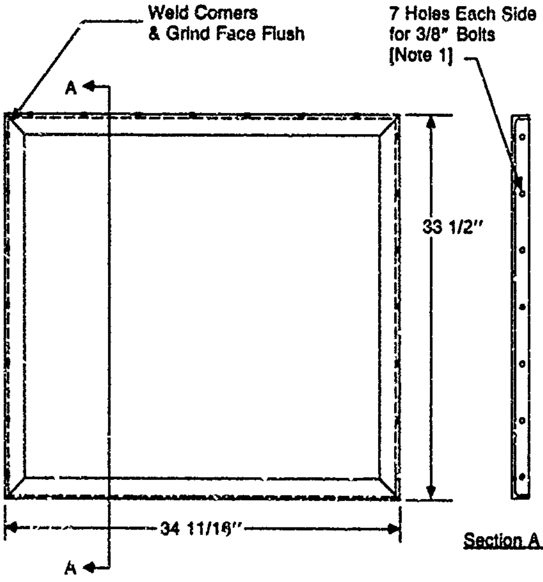
| | |
|---|---|
| BBN | Bolt Beranek and Newman Inc.<br>Cambridge Massachusetts |

DRAWING TITLE

GENERATOR INLET COWLING ASSEMBLY

| SIZE | CODE IDENT NO. | DRAWING NO. |
|---|---|---|
| A | | 4 |

| SCALE | WGT. EST/CALC | SHEET |
|---|---|---|
| None | | 29 OF 73 |




End View

Section A – A

Notes:

[1] Spacing to Match side and top Panels

Material: 1" x 1" x 3/16" Steel Angle
Quantity: 1

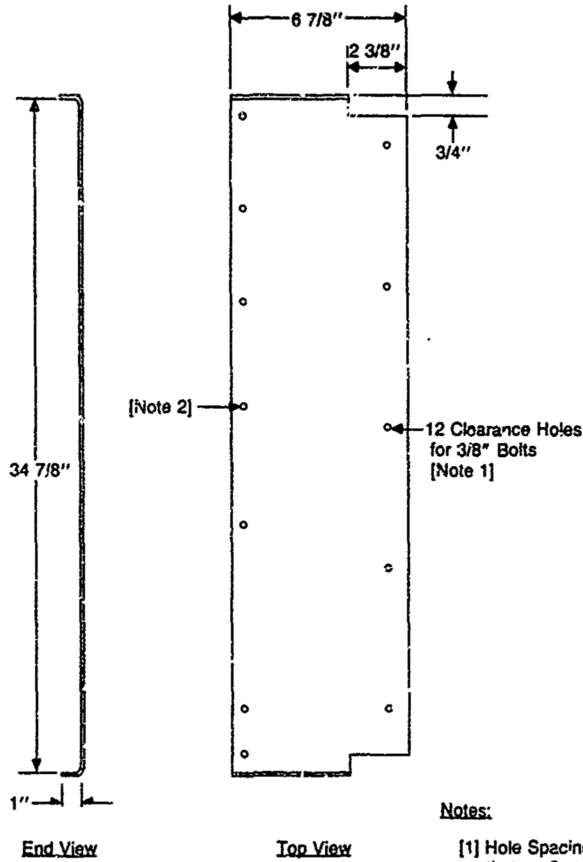
Bolt Beranek and Newman Inc.
Cambridge Massachusetts

DRAWING TITLE

GENERATOR INLET SILENCER MOUNTING FRAME

| SIZE | CODE IDENT NO. | DRAWING NO. |
|---|---|---|
| A | | 42 |

SCALE None | WGT: EST / CALC | SHEET 30 OF 73



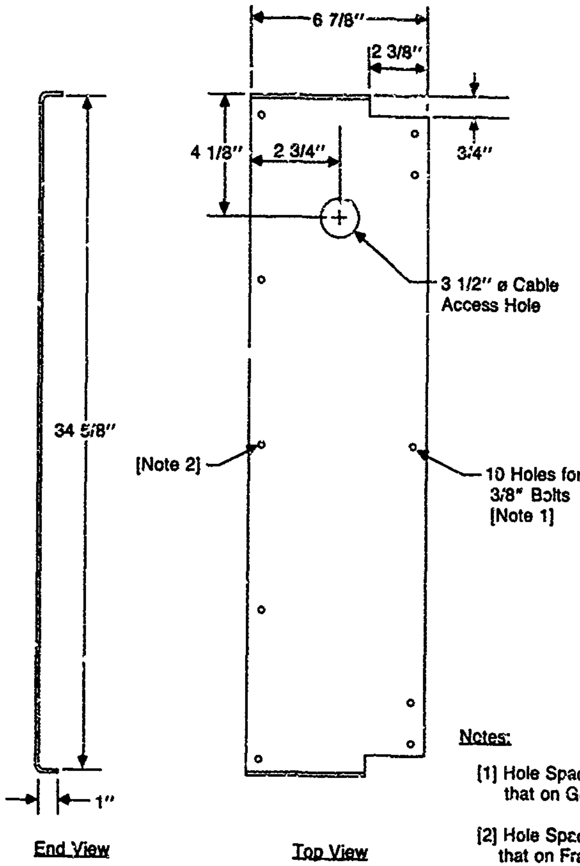

Notes:

[1] Hole Spacing to Match that on Generator

[2] Hole Spacing to Match that on Frame

Material: 16 ga Steel
Quantity: 1

| | | |
|---|---|---|
| bbn | Bolt Beranek and Newman Inc. Cambridge Massachusetts | |
| DRAWING TITLE: GENERATOR INLET COWLING TOP PANEL | | |
| SIZE: A | CODE IDENT NO. | DRAWING NO. 4B |
| SCALE: None | WGT: EST CALC | SHEET 31 OF 73 |



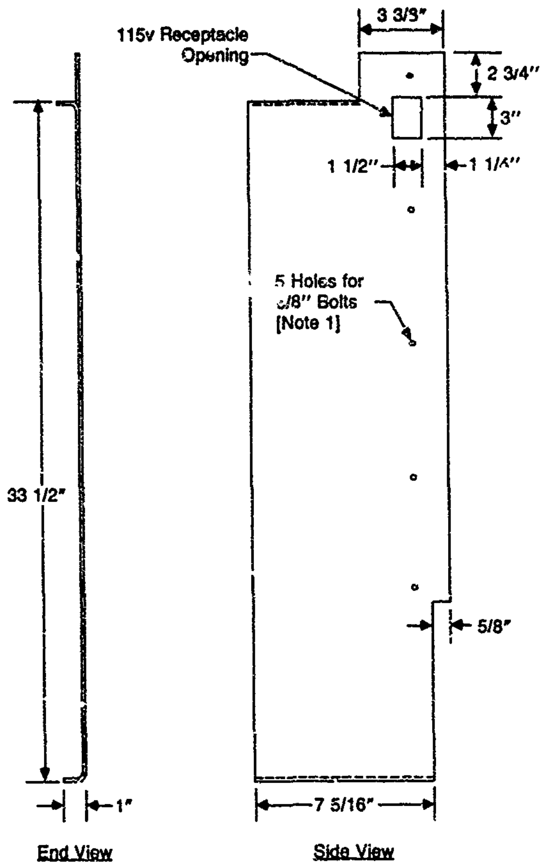

Notes:

[1] Hole Spacing to Match that on Generator

[2] Hole Spacing to Match that on Frame

Material: 16 ga Steel
Quantity: 1

| | | | |
|---|---|---|---|
| Bolt Beranek and Newman Inc. Cambridge Massachusetts | | | |
| DRAWING TITLE: GENERATOR INLET COWLING BOTTOM PANEL | | | |
| SIZE: A | CODE IDENT NO. | DRAWING NO.: 4C | |
| SCALE: None | WGT: EST / CALC | | SHEET 32 OF 73 |

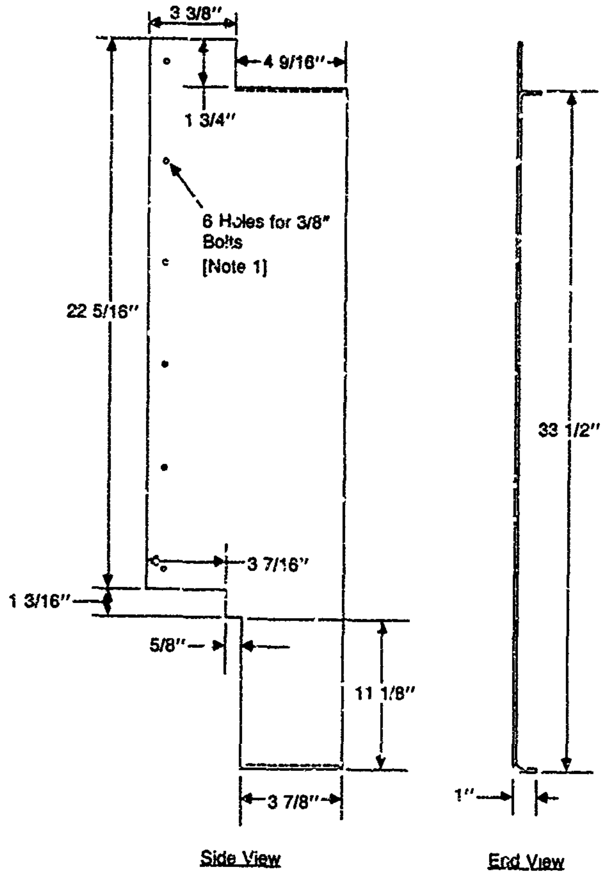



Notes:

[1] Hole spacing to Match that on generator

Material: 16 ga Steel
Quantity: 1

| Bolt Beranek and Newman Inc. Cambridge Massachusetts | | |
|---|---|---|
| DRAWING TITLE: GENERATOR INLET COWLING - RIGHT SIDE PANEL | | |
| SIZE: A | CODE IDENT NO. | DRAWING NO. 4D |
| SCALE: None | WGT: EST CALC | SHEET 33 OF 73 |



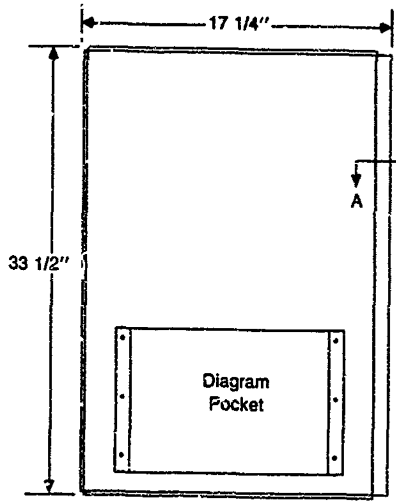

Notes:

[1] Hole Spacing to Match that on Generator

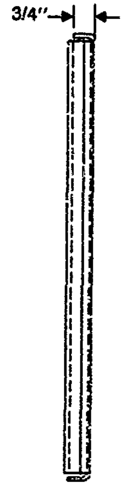
Material: 16 ga Steel
Quantity: 1

Bolt Beranek and Newman Inc.
Cambridge Massachusetts

| DRAWING TITLE | | |
|---|---|---|
| GENERATOR INLET COWLING - LEFT SIDE PANEL | | |
| SIZE A | CODE IDENT NO. | DRAWING NO. 4E |
| SCALE None | WGT: EST CALC | SHEET 34 OF 73 |




Inside View




Edge View

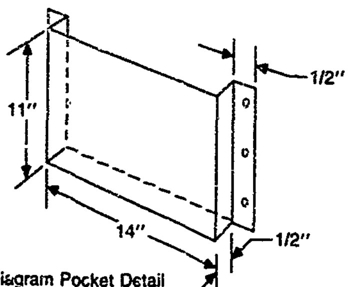
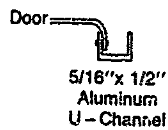


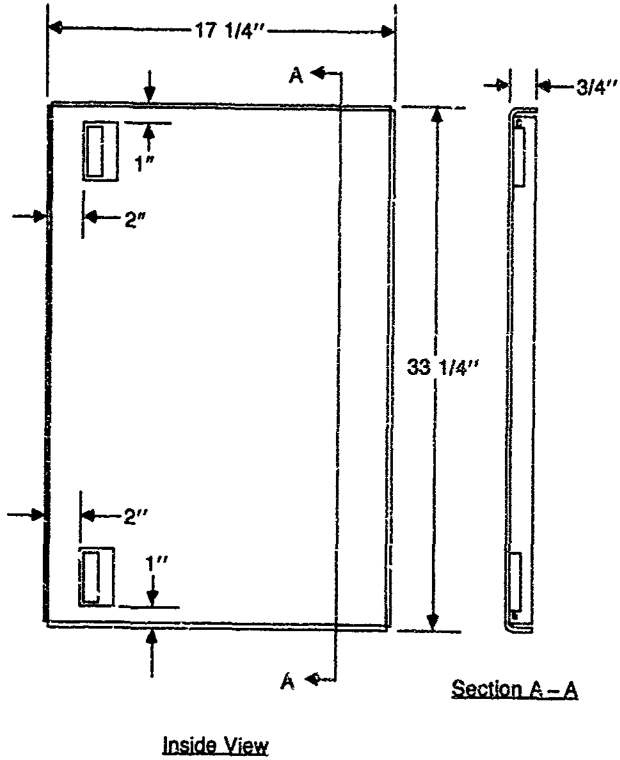

Diagram Pocket Detail
(20 Gage Sheet Steel)




Section A – A

Material: 16 ga Steel
Quantity: 1

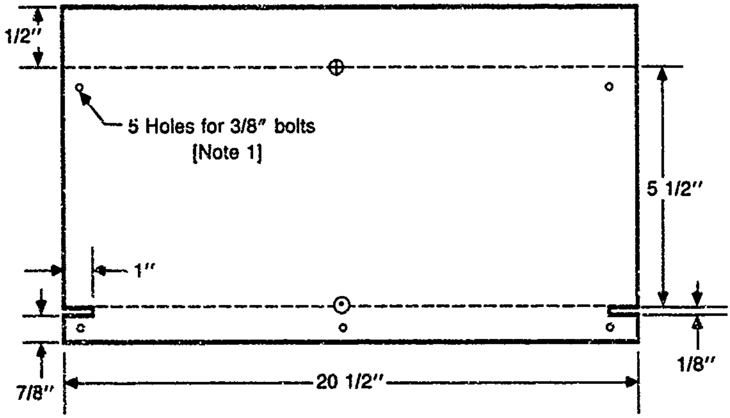
| | | | |
|---|---|---|---|
| bbn | Bolt Beranek and Newman Inc. Cambridge Massachusetts | | |
| DRAWING TITLE: GENERATOR INLET DOOR - RIGHT SIDE | | | |
| SIZE A | CODE IDENT NO. | DRAWING NO. 4F | |
| SCALE None | WGT: EST CALC | SHEET 35 OF 73 | |




Material: 16 ga Steel
Quantity: 1

Bolt Beranek and Newman Inc.
Cambridge Massachusetts

| | | | |
|---|---|---|---|
| DRAWING TITLE | GENERATOR INLET DOOR - LEFT SIDE | | |
| SIZE A | CODE IDENT NO. | DRAWING NO. 4G | |
| SCALE None | WGT: EST CALC | SHEET 36 OF 73 | |




Notes:

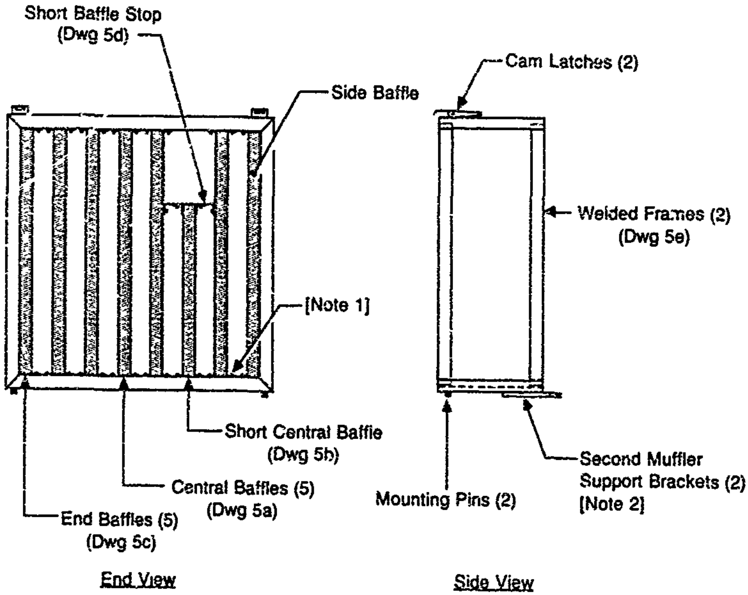
[1] Hole location to match those existing on generator inlet frame.

| | |
|---|---|
| ⊕ | Bend Up 90° |
| ⊙ | Bend Down 90° |

Material: 20 ga Steel
Quantity: 1

**Bolt Beranek and Newman Inc.**
Cambridge Massachusetts

| DRAWING TITLE | | | | |
|---|---|---|---|---|
| FUEL TANK GUARD | | | | |
| SIZE A | CODE IDENT NO. | DRAWING NO. 4H | | |
| SCALE None | WGT. EST CALC | SHEET 37 OF 73 | | |

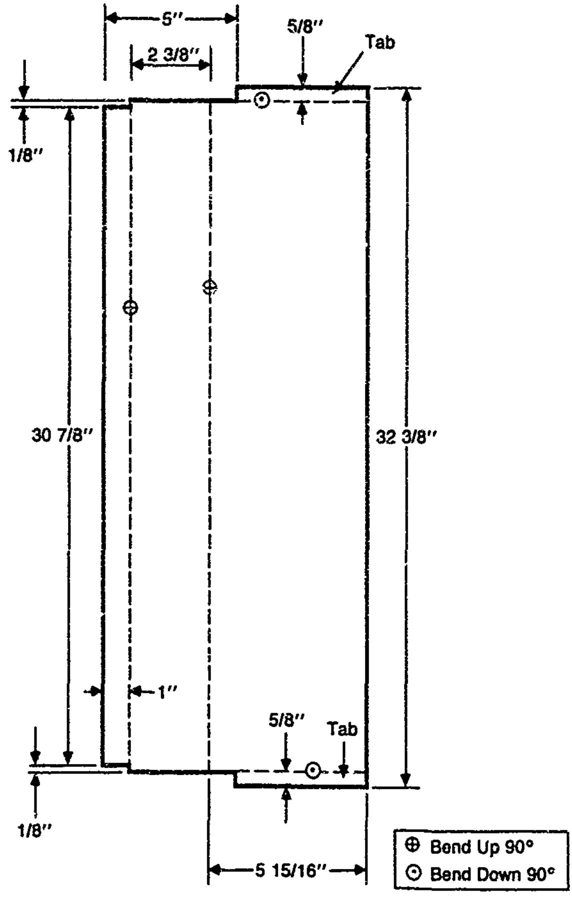



Notes:

[1] Baffles Riveted Through Tabs

[2] Support Brackets Required on Only One Muffler

| | | |
|---|---|---|
| Bolt Beranek and Newman Inc. Cambridge Massachusetts | | |
| DRAWING TITLE: GENERATOR INLET SILENCER ASSEMBLY | | |
| SIZE A | CODE IDENT NO. | DRAWING NO. 5 |
| SCALE None | WGT: EST CALC | SHEET 38 OF 73 |



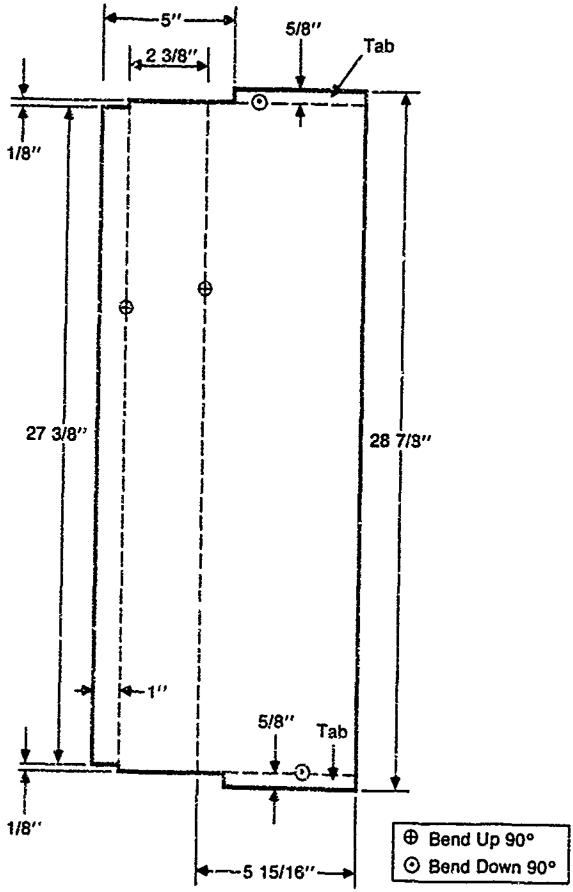

Material: 0.050 in. Perforated
Aluminum
Quantity: 20

**Bolt Beranek and Newman Inc.**
Cambridge Massachusetts

DRAWING TITLE
GENERATOR INLET SILENCER CENTRAL BAFFLE

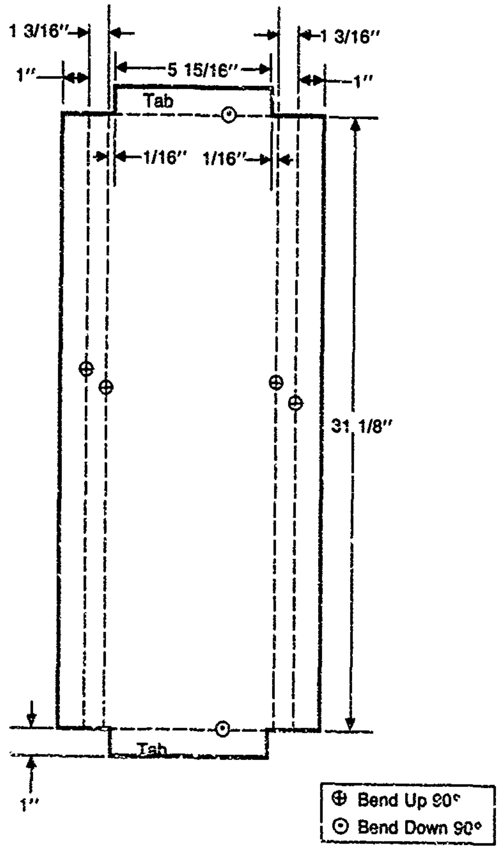
| SIZE | CODE IDENT NO. | DRAWING NO. |
|---|---|---|
| A | | 5A |

| SCALE None | WGT: EST CALC | SHEET 39 OF 73 |
|---|---|---|



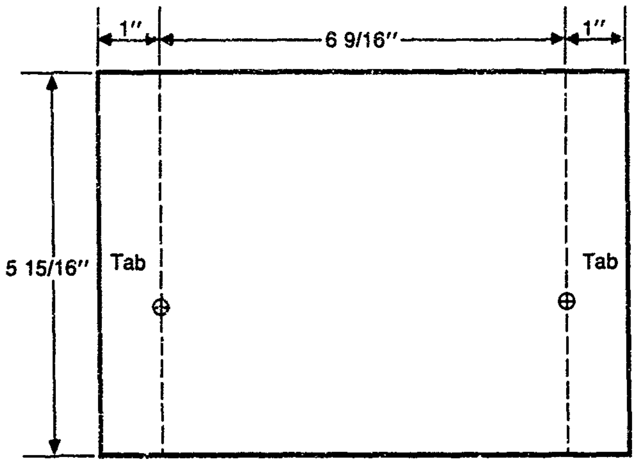

Material: 0.050 in. Perforated Aluminum
Quantity: 4

| | | | |
|---|---|---|---|
| Bolt Beranek and Newman Inc. Cambridge Massachusetts | | | |
| DRAWING TITLE: GENERATOR INLET SILENCER SHORT CENTRAL BAFFLE | | | |
| SIZE: A | CODE IDENT NO. | DRAWING NO. 5B | |
| SCALE None | WGT: EST CALC | SHEET 40 OF 73 | |




Material: 0.050 in. Perforated Aluminum
Quantity: 4

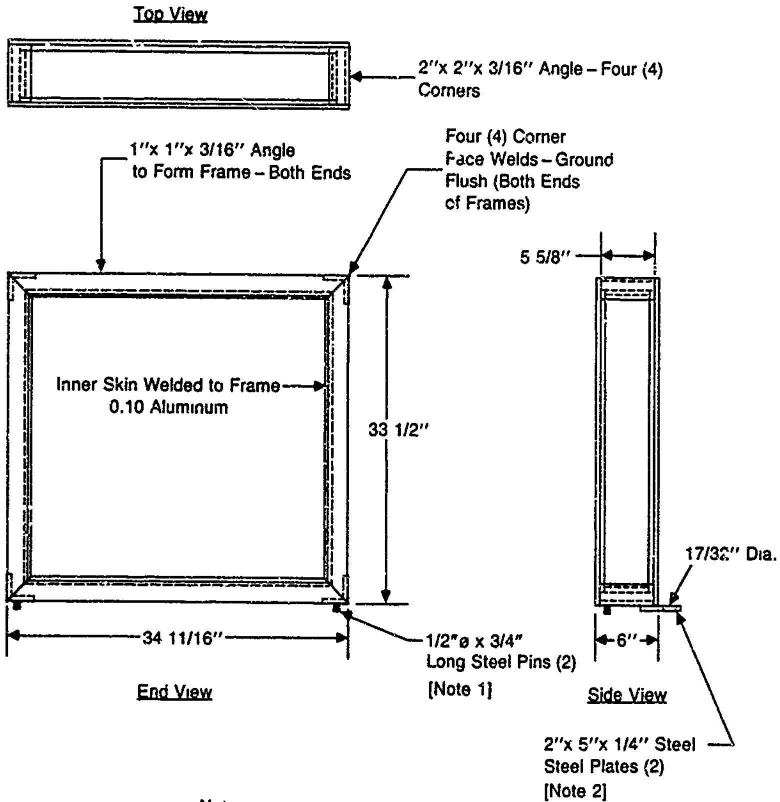
| | | | |
|---|---|---|---|
| Bolt Beranek and Newman Inc. Cambridge Massachusetts | | | |
| DRAWING TITLE: GENERATOR INLET SILENCER END BAFFLE | | | |
| SIZE: A | CODE IDENT NO. | DRAWING NO. 5C | |
| SCALE: None | WGT: EST CALC | SHEET 41 OF 73 | |




⊕ Bend Up 90°
⊙ Bend Down 90°

Material: 0.050 in. Perforated
Aluminum
Quantity: 2

| | | | |
|---|---|---|---|
| Bolt Beranek and Newman Inc. Cambridge Massachusetts | | | |
| DRAWING TITLE: GENERATOR INLET SILENCER SHORT BAFFLE STOP | | | |
| SIZE: A | CODE IDENT NO. | DRAWING NO. 5D | |
| SCALE None | WGT: EST CALC | SHEET 42 OF 73 | |




Notes:

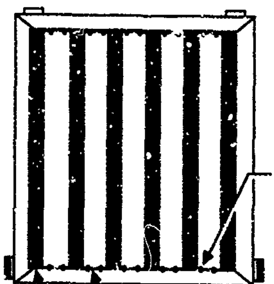
[1] Round Off Pins and Align to Fit Support Plates

[2] Align with Pins and Bolt to Frame

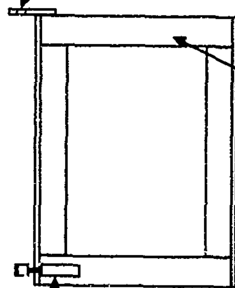
Material: Aluminum Angle
Quantity: 2

**Bolt Beranek and Newman Inc.**
Cambridge Massachusetts

| DRAWING TITLE | | |
|---|---|---|
| GENERATOR INLET SILENCER FRAME | | |
| SIZE A | CODE IDENT NO. | DRAWING NO. 5E |
| SCALE None | WGT. EST. CALC. | SHEET 43 OF 73 |




End View




Side View

Notes:

[1] Alaign Eyes and Latches to Fit Hooks on Generator, Bolt to Frame

[2] Baffles Riveted to Frame Through Tabs

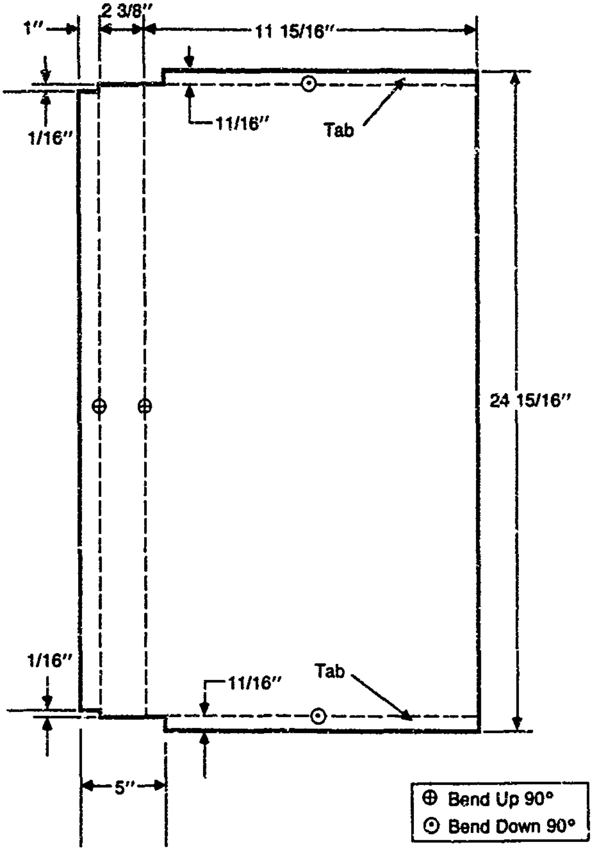
**Bolt Beranek and Newman Inc.**
Cambridge Massachusetts

DRAWING TITLE

RADIATOR DISCHARGE SILENCER ASSEMBLY

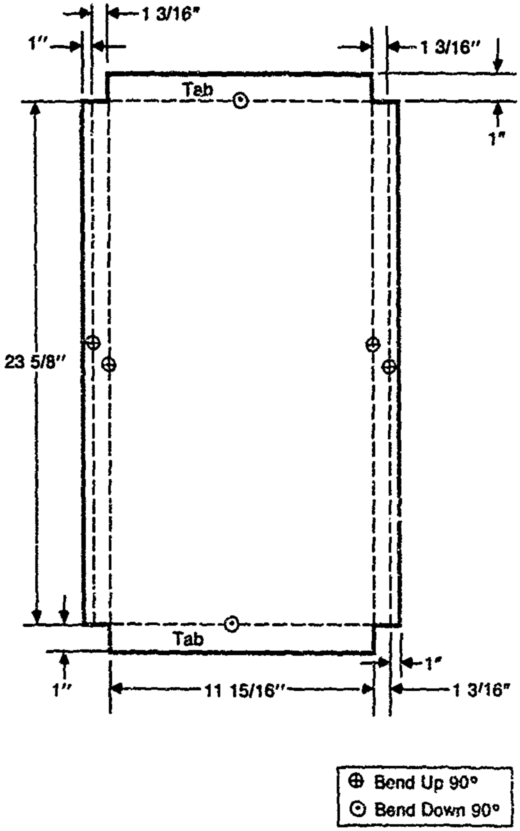
| SIZE | CODE IDENT NO. | DRAWING NO. |
|---|---|---|
| A | | 6 |

| SCALE | WGT: EST. CALC. | SHEET |
|---|---|---|
| None | | 44 OF 73 |




Material: 0.050 in. Perforated
Aluminum
Quantity: 8

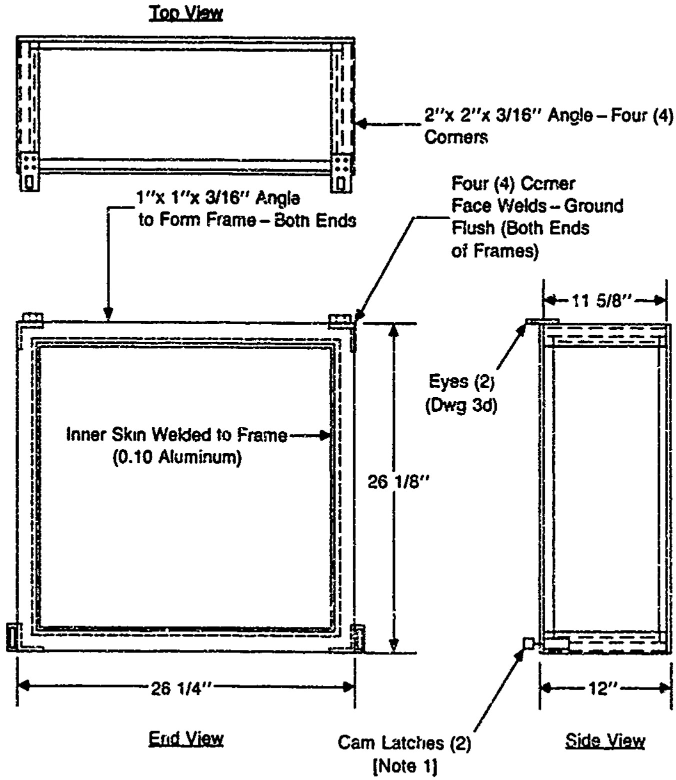
| | | |
|---|---|---|
| Bolt Beranek and Newman Inc. Cambridge Massachusetts | | |
| DRAWING TITLE RADIATOR DISCHARGE SILENCER CENTRAL BAFFLE | | |
| SIZE A | CODE IDENT NO. | DRAWING NO. 6A |
| SCALE None | WGT: EST CALC | SHEET 45 OF 73 |




Material: 0.050 in. Perforated
Aluminum
Quantity: 2

| | |
|---|---|
| bbn | Bolt Beranek and Newman Inc. Cambridge Massachusetts |

| DRAWING TITLE | | |
|---|---|---|
| RADIATOR DISCHARGE SILENCER END BAFFLE | | |
| SIZE A | CODE IDENT NO. | DRAWING NO. 6B |
| SCALE None | WGT: EST CALC | SHEET 46 OF 73 |



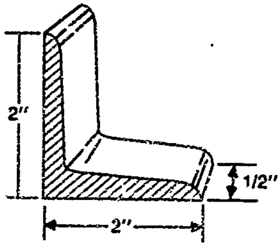

Notes:

[1] Align Latches with Strikes to be Mounted on Muffler Interface Frame

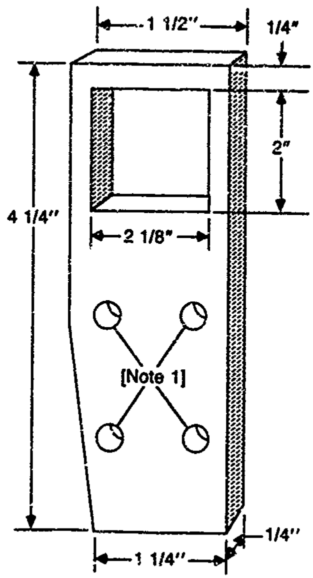
Material: Aluminum Angle
Quantity: 1

**Bolt Beranek and Newman Inc.**
Cambridge Massachusetts

| DRAWING TITLE | | |
|---|---|---|
| RADIATOR DISCHARGE SILENCER FRAME | | |
| SIZE: A | CODE IDENT NO. | DRAWING NO. 6C |
| SCALE None | WGT. EST CALC | SHEET 47 OF 73 |




**Hooks (2)**
2" x 2" x 3/16" steel angle
To be Welded to Radiator discharge muffler interface frame.

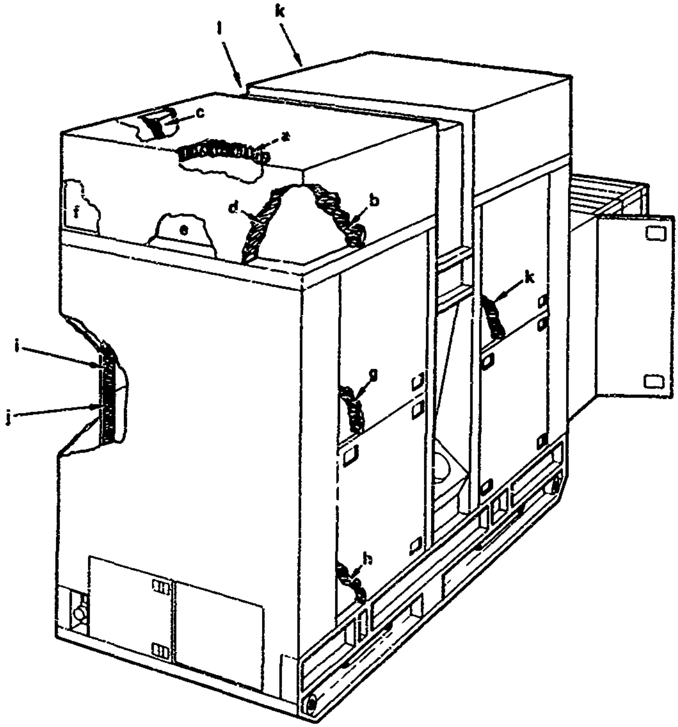



**Eyes (2):**
To be mounted on radiator discharge muffler frame & aligned with hooks.

Notes:
[1] Four holes for 1/4 – 20 screws – match location on muffler frame.

Material: Steel
Quantity: 2 ea

| | |
|---|---|
| Bolt Beranek and Newman Inc. Cambridge Massachusetts | |
| DRAWING TITLE: RADIATOR DISCHARGE SILENCER MOUNTING HOOKS | |
| SIZE: A | CODE IDENT NO.: | DRAWING NO.: 6D |
| SCALE: None | WGT: EST CALC | SHEET 48 OF 73 |



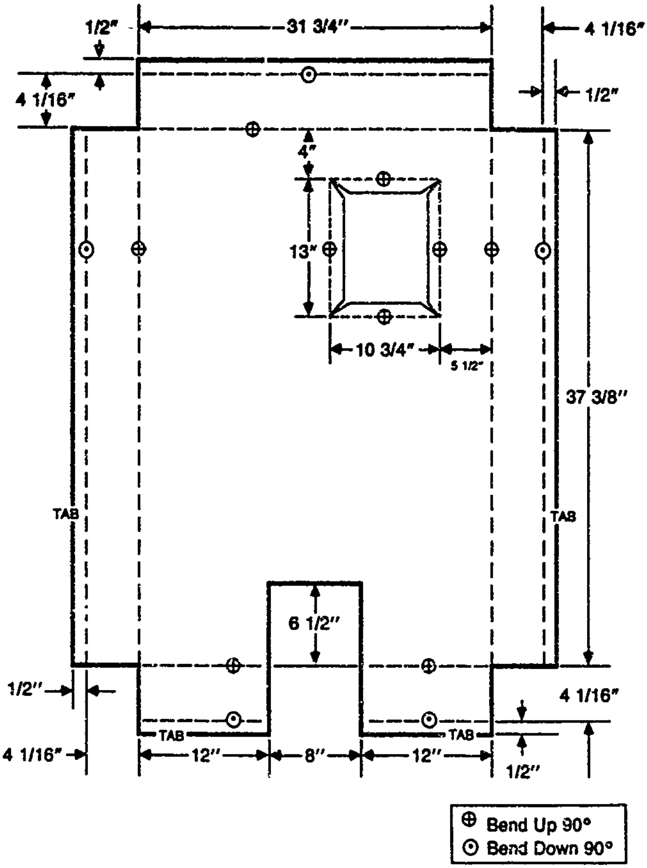

Bolt Beranek and Newman Inc.
Cambridge Massachusetts

DRAWING TITLE

ENCLOSURE SOUND ABSORPTION TREATMENT

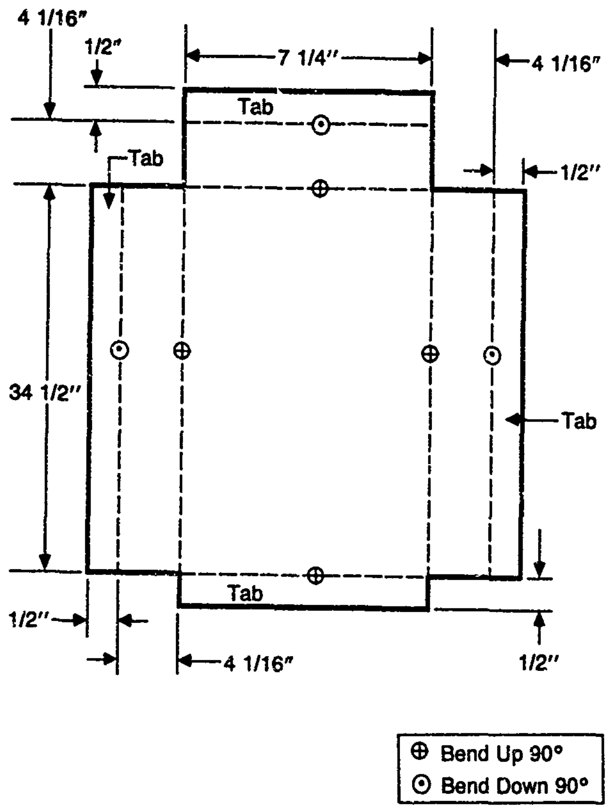
| SIZE | CODE IDENT NO. | DRAWING NO. |
|---|---|---|
| A | | 7 |

| SCALE None | WGT: EST CALC | SHEET 49 OF 73 |
|---|---|---|



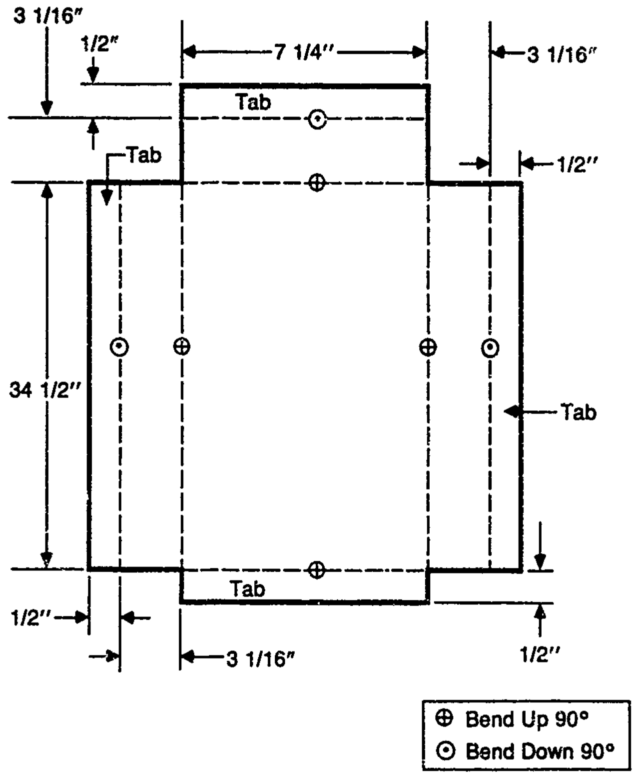

Material: 0.050 in. Perforated
Aluminum
Quantity: 1

| | |
|---|---|
| Bolt Beranek and Newman Inc. Cambridge Massachusetts | |
| DRAWING TITLE | ROOF ABSORPTION BAFFLE - DIESEL END |
| SIZE A | CODE IDENT NO. | DRAWING NO. 7A |
| SCALE None | WGT: EST CALC | SHEET 50 OF 73 |



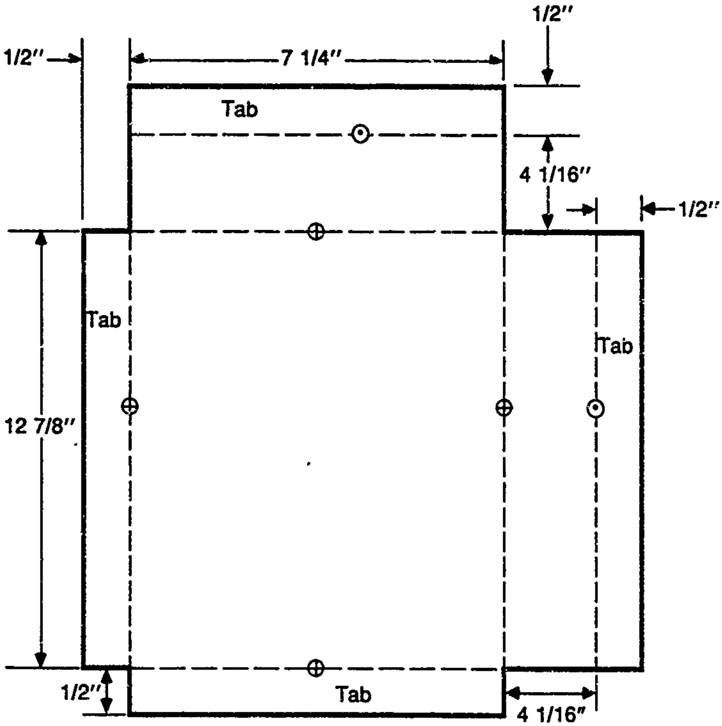

Material: 0.050 in. Perforated
Aluminum
Quantity: 1

| | | | |
|---|---|---|---|
| Bolt Beranek and Newman Inc. Cambridge Massachusetts | | | |
| DRAWING TITLE: VALANCE ABSORPTION BAFFLE - INTAKE SIDE | | | |
| SIZE A | CODE IDENT NO. | DRAWING NO. 7B | |
| SCALE None | WGT: EST CALC | SHEET 51 OF 73 | |




Material: 0.050 in. Perforated
Aluminum
Quantity: 1

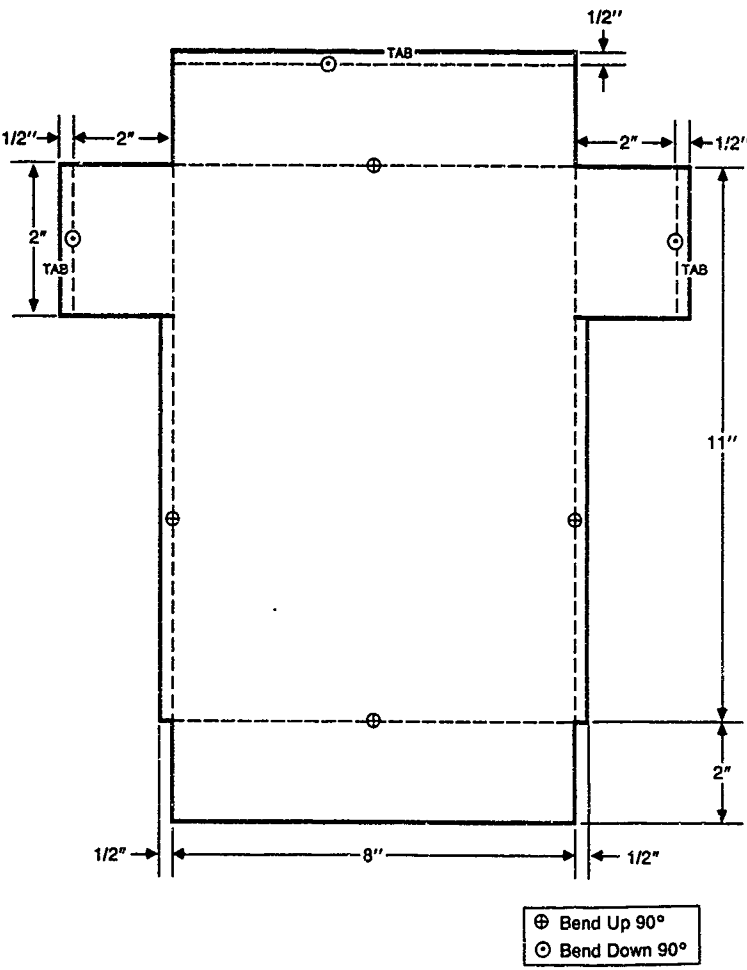
| Bolt Beranek and Newman Inc. Cambridge Massachusetts | | |
|---|---|---|
| DRAWING TITLE: VALANCE ABSORPTION BAFFLE - EXHAUST SIDE | | |
| SIZE: A | CODE IDENT NO. | DRAWING NO.: 7C |
| SCALE: None | WGT: EST CALC | SHEET 52 OF 73 |




⊕ Bend Up 90°
⊙ Bend Down 90°

Material: 0.050 in. Perforated Aluminum
Quantity: 1

| | | | |
|---|---|---|---|
| Bolt Beranek and Newman Inc. Cambridge Massachusetts | | | |
| DRAWING TITLE: VALANCE ABSORPTION BAFFLE - FRONT LEFT | | | |
| SIZE A | CODE IDENT NO. | DRAWING NO. 7D | |
| SCALE None | WGT: EST CALC | SHEET 53 OF 73 | |



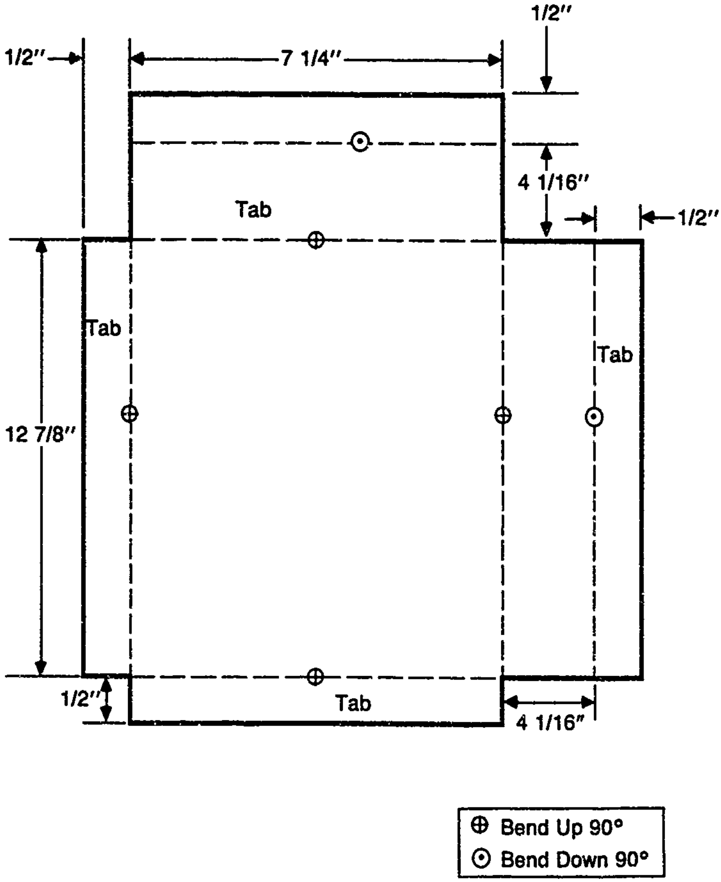

Material: 0.050 in. Perforated
Aluminum
Quantity: 1

**Bolt Beranek and Newman Inc.**
Cambridge Massachusetts

DRAWING TITLE
VALANCE ABSORPTION BAFFLE - FRONT CENTER

| SIZE | CODE IDENT NO. | DRAWING NO. |
|---|---|---|
| A | | 7E |

| SCALE | WGT: EST CALC | SHEET |
|---|---|---|
| None | | 54 OF 73 |




Material: 0.050 in. Perforated
Aluminum
Quantity: 1

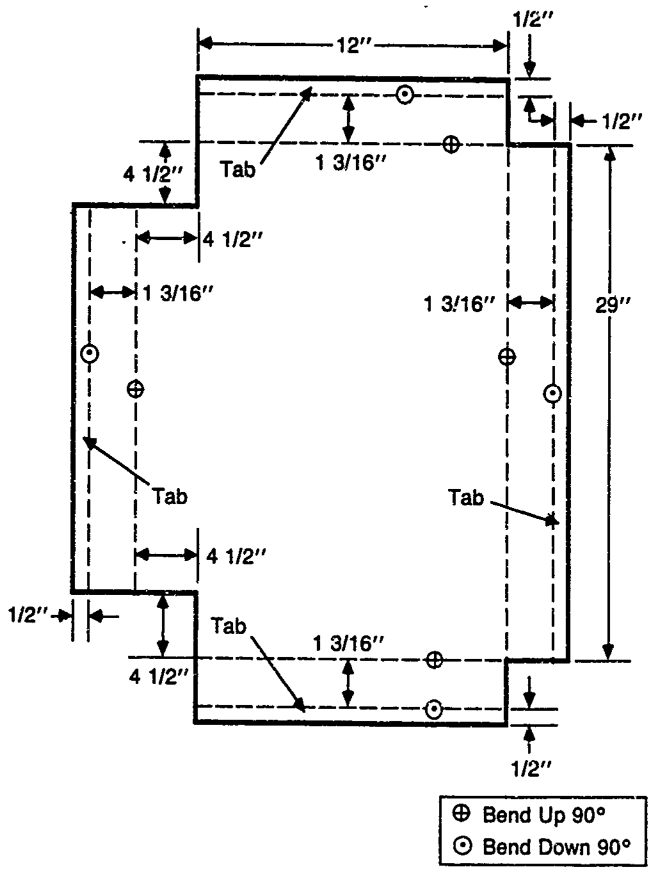
**Bolt Beranek and Newman Inc.**
Cambridge Massachusetts

DRAWING TITLE

VALANCE ABSORPTION BAFFLE - FRONT RIGHT

| SIZE | CODE IDENT NO. | DRAWING NO. |
|---|---|---|
| A | | 7F |

| SCALE None | WGT: EST CALC | SHEET 55 OF 73 |
|---|---|---|




Material: 0.050 in. Perforated
Aluminum
Quantity: 1

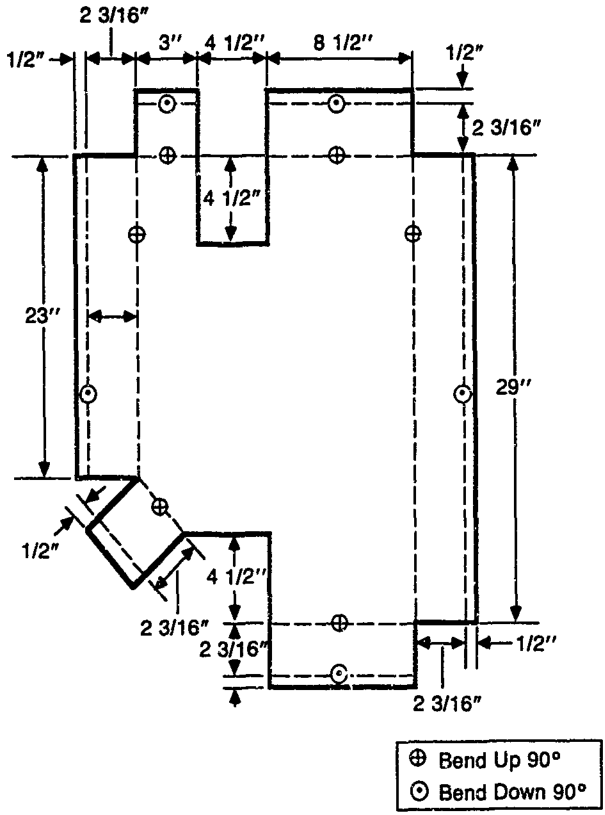
| | |
|---|---|
| bbn | **Bolt Beranek and Newman Inc.** Cambridge Massachusetts |

DRAWING TITLE

DOOR ABSORPTION BAFFLE - UPPER DIESEL INTAKE DOOR

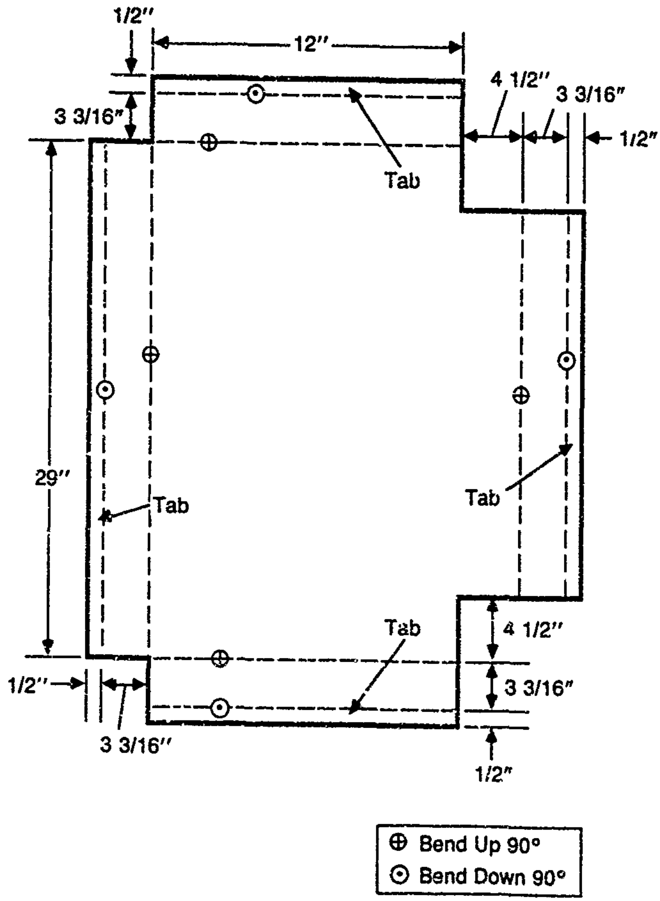
| SIZE | CODE IDENT NO. | DRAWING NO. |
|---|---|---|
| A | | 7G |

| SCALE | WGT: EST CALC | SHEET |
|---|---|---|
| None | | 56 OF 73 |




Material: 0.050 in. Perforated
Aluminum
Quantity: 1

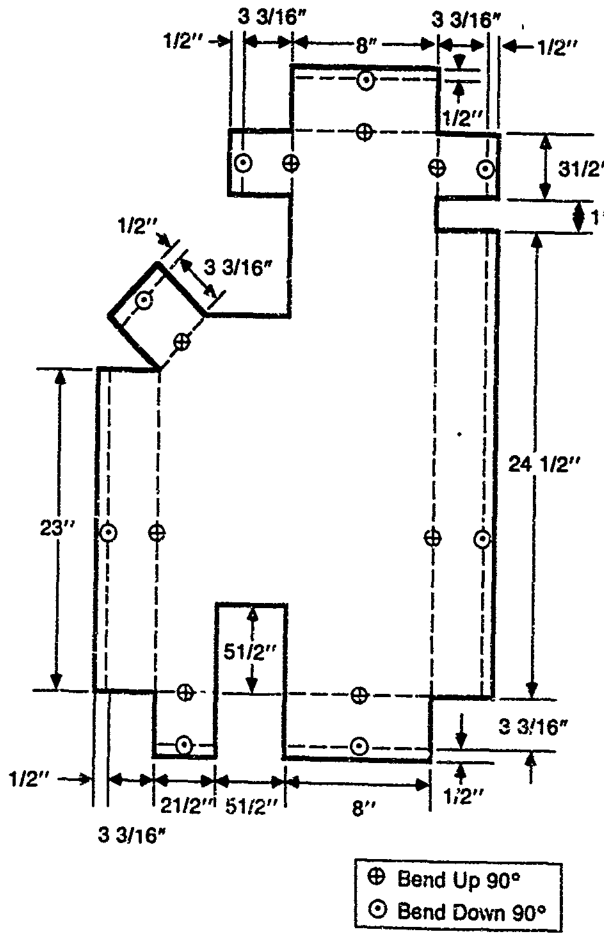
| | | | |
|---|---|---|---|
| Bolt Beranek and Newman Inc. Cambridge Massachusetts | | | |
| DRAWING TITLE: DOOR ABSORPTION BAFFLE - LOWER DIESEL INTAKE SIDE | | | |
| SIZE: A | CODE IDENT NO. | DRAWING NO.: 7H | |
| SCALE: None | WGT: EST CALC | SHEET 57 OF 73 | |




Material: 0.050 in. Perforated
Aluminum
Quantity: 1

Bolt Beranek and Newman Inc.
Cambridge Massachusetts

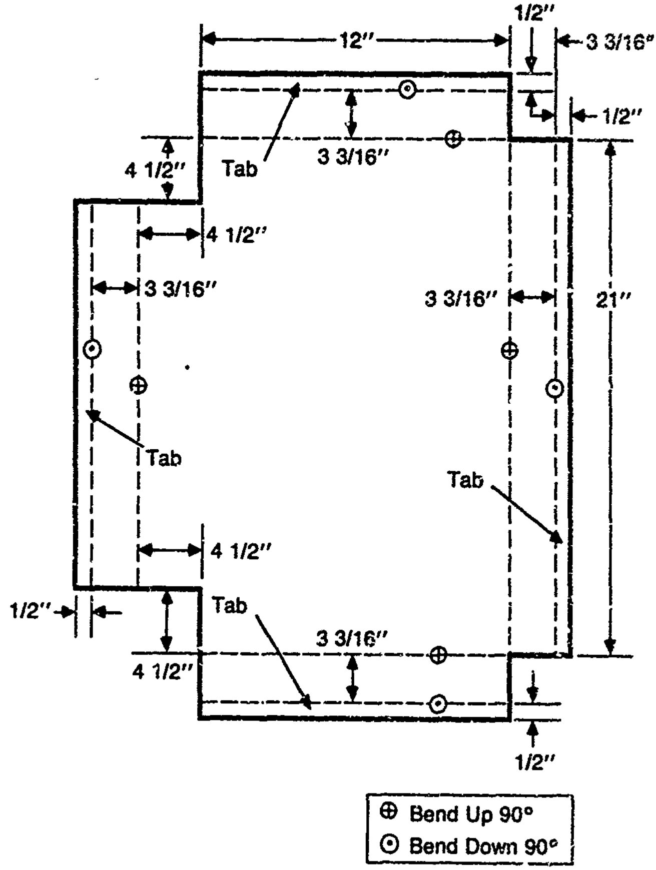
| DRAWING TITLE | | | |
|---|---|---|---|
| DOOR ABSORPTION BAFFLE - UPPER DIESEL EXHAUST SIDE | | | |
| SIZE A | CODE IDENT NO. | DRAWING NO. 71 | |
| SCALE None | WGT: EST CALC | SHEET 58 OF 73 | |




Material: 0.050 in. Perforated
Aluminum
Quantity: 1

Bolt Beranek and Newman Inc.
Cambridge Massachusetts

| DRAWING TITLE | | |
|---|---|---|
| DOOR ABSORPTION BAFFLE - LOWER DIESEL EXHAUST SIDE | | |
| SIZE A | CODE IDENT NO. | DRAWING NO. 7J |
| SCALE None | WGT: EST CALC | SHEET 59 OF 73 |




Material: 0.050 in. Perforated Aluminum
Quantity: 2

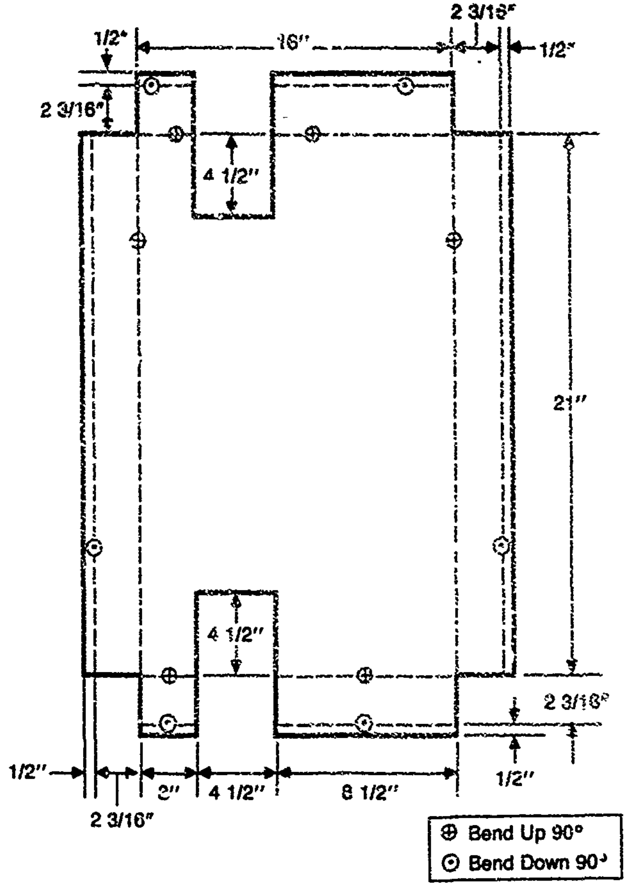
Bolt Beranek and Newman Inc.
Cambridge Massachusetts

DRAWING TITLE

DOOR ABSORPTION BAFFLE - UPPER GENERATOR INTAKE SIDE

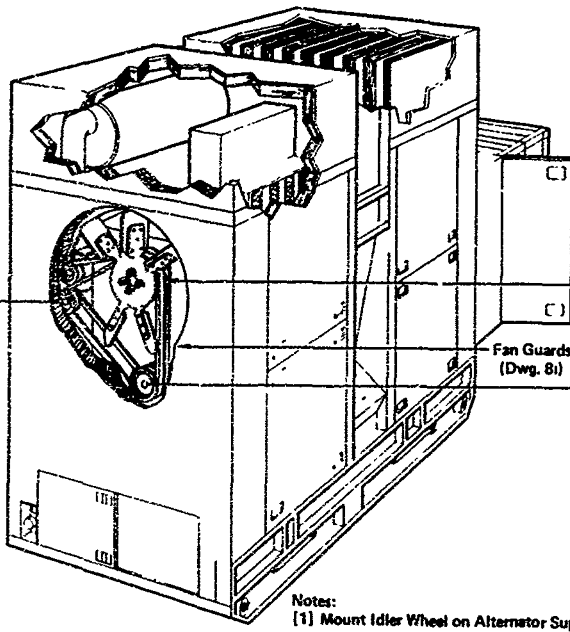
| SIZE | CODE IDENT NO. | DRAWING NO. |
| --- | --- | --- |
| A | | 7K |

SCALE None | WGT: EST/CALC | SHEET 60 OF 73



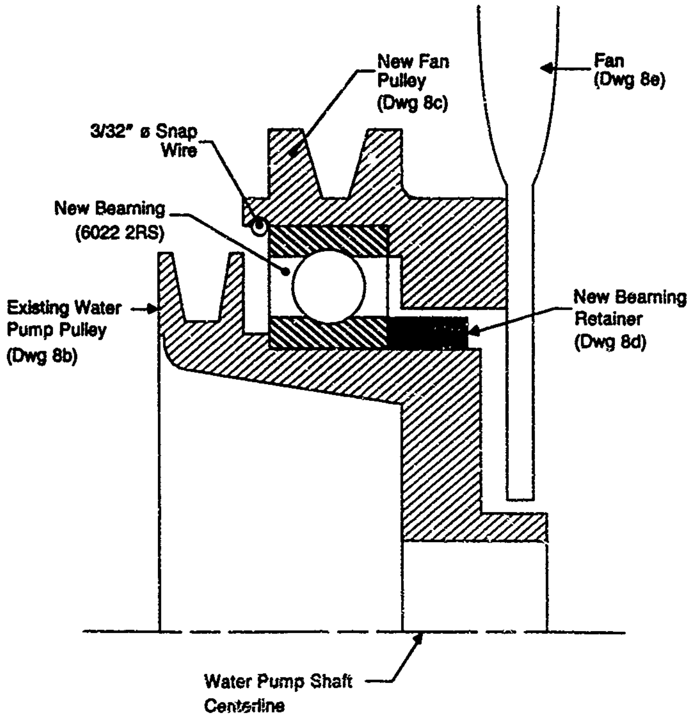

Material: 0.050 in. Perforated Aluminum
Quantity: 1

| | | |
|---|---|---|
| Bolt Beranek and Newman Inc. Cambridge Massachusetts | | |
| DRAWING TITLE: DOOR ABSORPTION BAFFLE - LOWER GENERATOR EXHAUST SIDE | | |
| SIZE A | CODE IDENT NO. | DRAWING NO. 7L |
| SCALE None | WGT: EST CALC | SHEET 61 OF 73 |



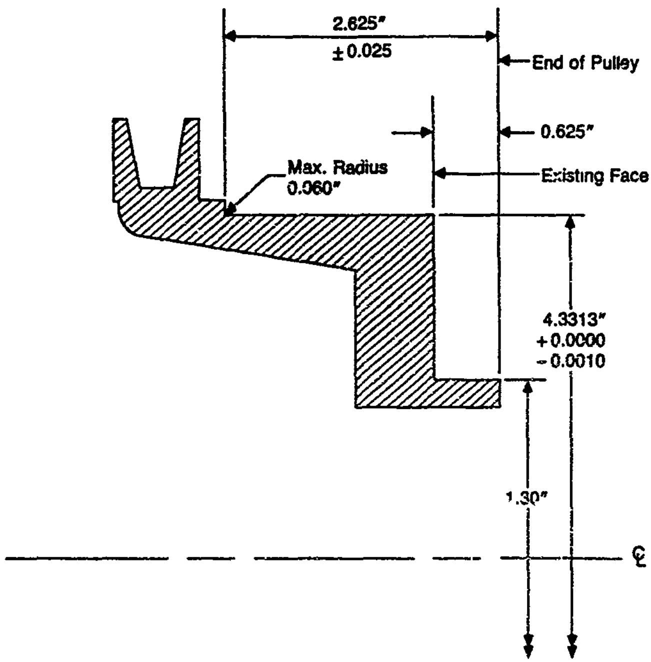

Notes:
(1) Mount Idler Wheel on Alternator Support and Adjust to Suit.

| | | | |
|---|---|---|---|
| bbn | Bolt Beranek and Newman Inc. Cambridge Massachusetts | | |
| DRAWING TITLE<br>FAN MODIFICATION ASSEMBLY | | | |
| SIZE A | CODE IDENT NO. | DRAWING NO. 8 | |
| SCALE None | WGT: EST CALC | SHEET 62 OF 73 | |



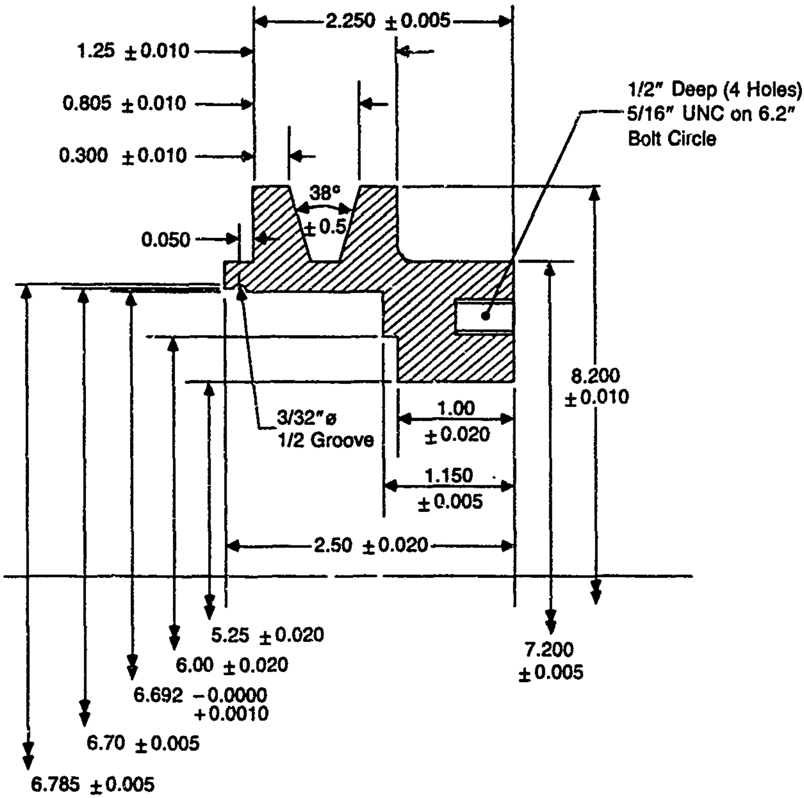

**Bolt Beranek and Newman Inc.**
Cambridge Massachusetts

| | | | |
|---|---|---|---|
| DRAWING TITLE | | | |
| FAN AND WATER PUMP PULLEY ASSEMBLY | | | |
| SIZE A | CODE IDENT NO. | DRAWING NO. 8A | |
| SCALE None | WGT: EST CALC | SHEET 63 OF 73 | |



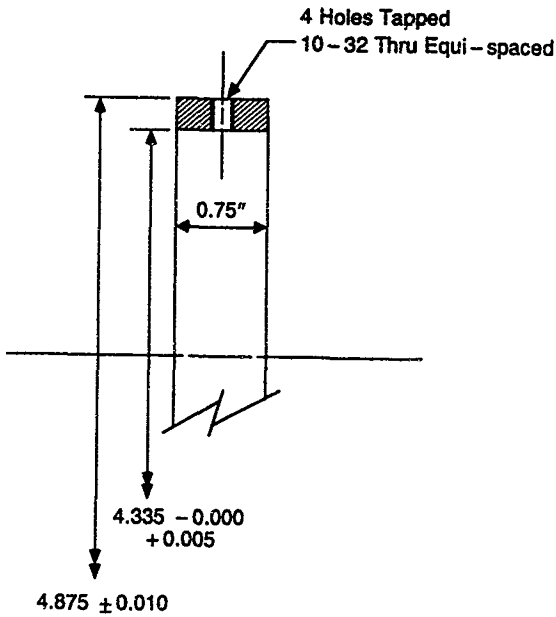

**Bolt Beranek and Newman Inc.**
Cambridge Massachusetts

| | | | |
|---|---|---|---|
| DRAWING TITLE | WATER PUMP PULLEY MODIFICATIONS | | |
| SIZE A | CODE IDENT NO. | DRAWING NO. 8B | |
| SCALE None | WGT: EST CALC | SHEET 64 OF 73 | |




Material: Aluminum
Quantity: 1

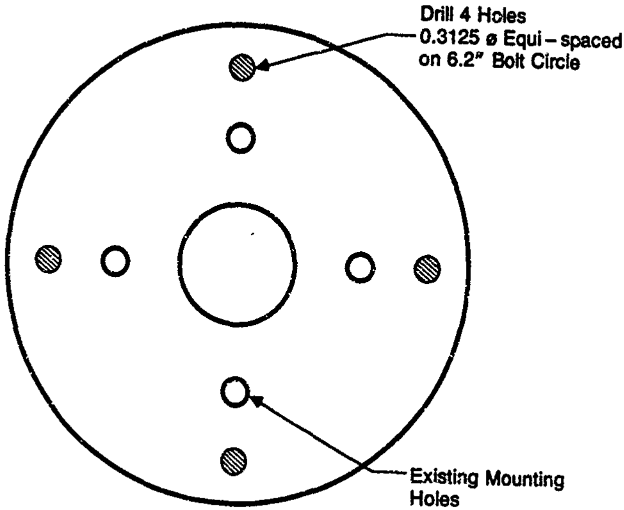
| | | | |
|---|---|---|---|
| Bolt Beranek and Newman Inc. Cambridge Massachusetts | | | |
| DRAWING TITLE: NEW FAN PULLEY | | | |
| SIZE: A | CODE IDENT NO. | DRAWING NO.: 8C | |
| SCALE: None | WGT: EST CALC | SHEET 65 OF 73 | |




Material: Steel
Quantity: 1

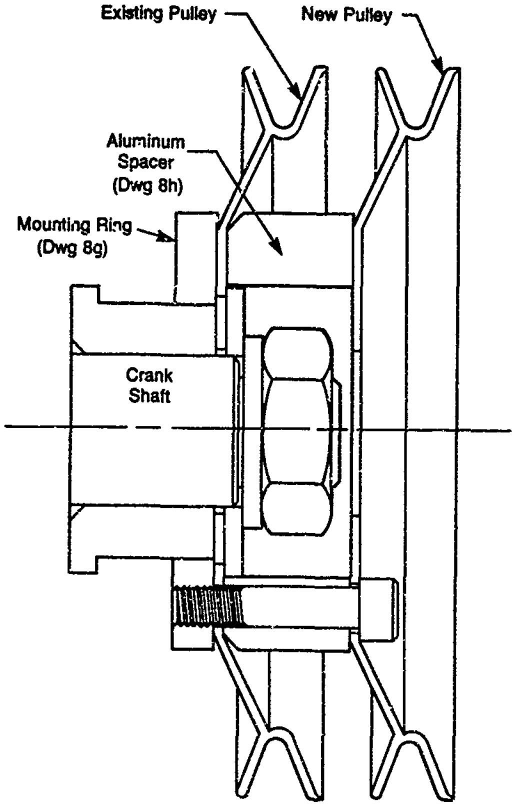
**Bolt Beranek and Newman Inc.**
Cambridge Massachusetts

| DRAWING TITLE | | |
|---|---|---|
| FAN PULLEY BEARING RETAINER | | |
| SIZE: A | CODE IDENT NO. | DRAWING NO. 8D |
| SCALE: None | WGT: EST CALC | SHEET 66 OF 73 |

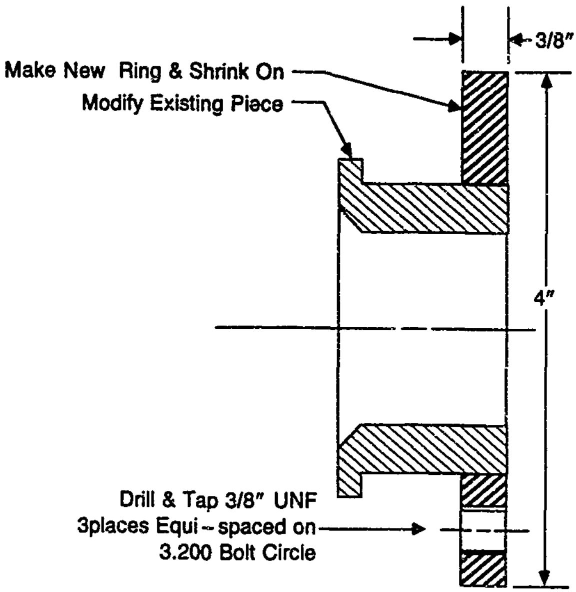



**Bolt Beranek and Newman Inc.**
Cambridge Massachusetts

| DRAWING TITLE | | | |
|---|---|---|---|
| FAN HUB MODIFICATIONS | | | |
| SIZE A | CODE IDENT NO. | DRAWING NO. 8E | |
| SCALE None | WGT: EST CALC | SHEET 67 OF 73 | |

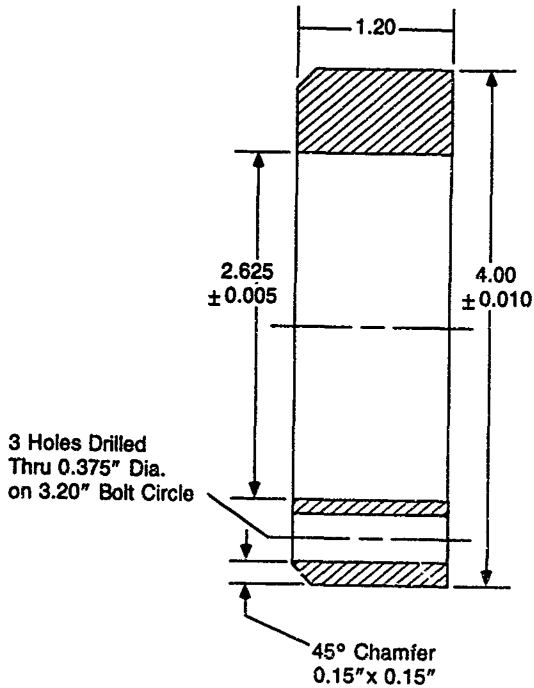



| | | | |
|---|---|---|---|
| Bolt Beranek and Newman Inc. Cambridge Massachusetts | | | |
| DRAWING TITLE<br>CRANK SHAFT PULLEY ASSEMBLY | | | |
| SIZE A | CODE IDENT NO. | DRAWING NO. 8F | |
| SCALE None | WGT: EST CALC | | SHEET 68 OF 73 |



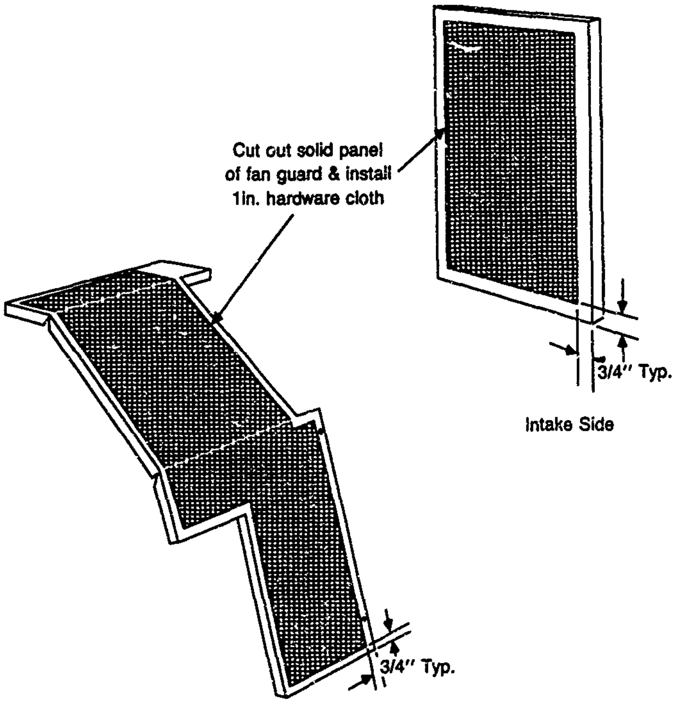

Material: Steel
Quantity: 1

| Bolt Beranek and Newman Inc. Cambridge Massachusetts | | |
|---|---|---|
| DRAWING TITLE: CRANK SHAFT PULLEY MOUNTING RING | | |
| SIZE: A | CODE IDENT NO. | DRAWING NO. 8G |
| SCALE None | WGT: EST CALC | SHEET 69 OF 73 |




Material: Aluminum
Quantity: 1

| | | |
|---|---|---|
| Bolt Beranek and Newman Inc. Cambridge Massachusetts | | |
| DRAWING TITLE: CRANK SHAFT PULLEY SPACER | | |
| SIZE A | CODE IDENT NO. | DRAWING NO. 8H |
| SCALE None | WGT: EST CALC | SHEET 70 OF 73 |



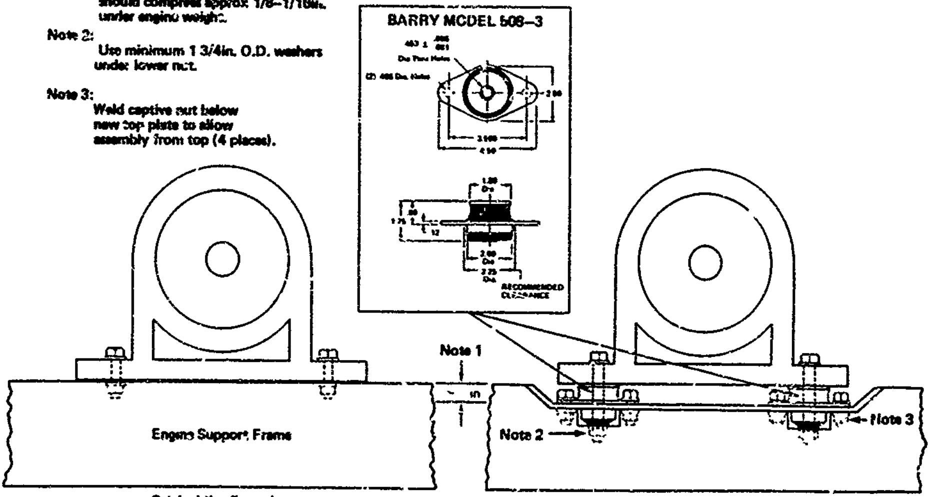

Bolt Beranek and Newman Inc.
Cambridge Massachusetts

| | | | |
|---|---|---|---|
| DRAWING TITLE | | | |
| FAN GUARD MODIFICATIONS | | | |
| SIZE A | CODE IDENT NO. | DRAWING NO. 8I | |
| SCALE None | WGT: EST CALC | SHEET 71 OF 73 | |

Note 1:
Notch top of beam to keep height constant. Note mounts should compress approx 1/8–1/16in. under engine weight.

Note 2:
Use minimum 1 3/4in. O.D. washers under lower nut.

Note 3:
Weld captive nut below new top plate to allow assembly from top (4 places).



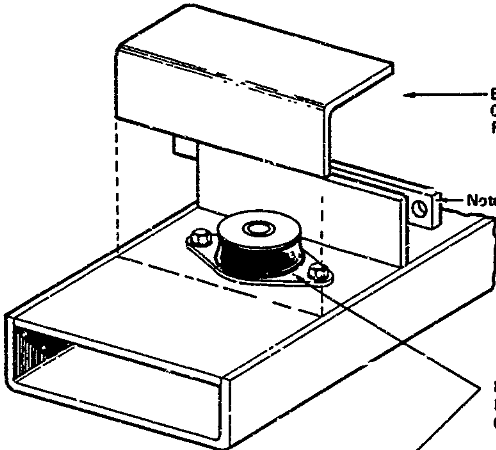

Original Configuration        New Configuration


Bolt Beranek and Newman Inc.
Cambridge Massachusetts

DRAWING TITLE

ENGINE VIBRATION ISOLATION ASSEMBLY

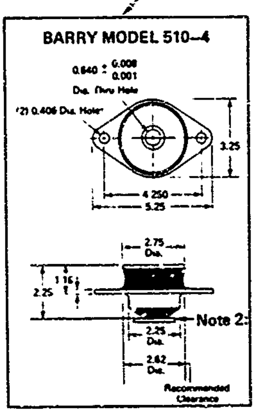
| SIZE | CODE IDENT NO. | DRAWING NO. | |
|---|---|---|---|
| A | | 9A | |
| SCALE None | WGT: EST CALC | SHEET 72 OF 73 | |




Note 3:
Drill & tap beam to allow assembly from top.

Note 4:
Shim to proper height.

Note 2.
Use 1 3/4–2 in. O.D. washers




| | | | |
|---|---|---|---|
| Bolt Beranek and Newman Inc. Cambridge Massachusetts | | | |
| DRAWING TITLE: GENERATOR VIBRATION ISOLATION ASSEMBLY | | | |
| SIZE: A | CODE IDENT NO. | DRAWING NO. 9B | |
| SCALE: None | WGT: EST / CALC | SHEET 73 OF 73 | |